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Development and Evaluation of a Computer-Based Clinical Information System for the Intensive Care Unit

by

© Philip Wayne Burridge

A THESIS

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SUPERVISOR

DATE December 2, 1982

To my parents and teachers who helped

me understand

and

to my wife who understood me

ABSTRACT

Health care professionals are confronted daily with a deluge of new medical information. The ability to deliver standardized, high quality health care is based on the clinician's initiative to seek and evaluate this new information. In addition, human memory is often imperfect and is further restricted by fatigue, stress and a demanding work schedule.

A computerized bedside clinical information system, the CLINICAL REFERENCE LIBRARY, was developed to facilitate the management of patient care and to provide physicians-in-training and paramedical personnel with relevant clinical information about common disease processes and problems encountered in the intensive care unit.

The CLINICAL REFERENCE LIBRARY, developed and described in this thesis, is a subsystem of the HP 5600A Patient Data Management System. It contains 20 information modules. Each module consists of several individual computer displays. Where applicable, information basic for any single problem is classified under the following headings: definition, incidence, etiology, bacteriology, pathology, pathophysiology, clinical course, diagnosis, treatment, complications, prognosis, and references. Topics include medical record keeping, airway management, pulmonary physiology, acid-base regulation, acid-base abnormalities, gas transport, pulmonary embolism, Adult Respiratory Distress Syndrome, septic shock, aspiration pneumonia, poisonings, antimicrobial therapy, adverse drug interactions, pediatric medications, nutritional support, burns, hemodynamic monitoring, cardiac arrhythmias, brain resuscitation and hypothermia.

The system is menu-driven and self-instructing. The user is able to

flip rapidly back and forth through any module, or from one module to another, much as one would flip through a book. Logging and analysis of user performance are also incorporated into the CLINICAL REFERENCE LIBRARY.

Evaluation of the CLINICAL REFERENCE LIBRARY was in the form of a classical non-randomized, pre-test - post-test, control-experimental research paradigm. Three specific findings emerged from the data:

1) medical students and residents exposed to the CLINICAL REFERENCE LIBRARY "acquired" more knowledge than their counterparts who used conventional teaching methods
2) medical students and nurses accessed the CLINICAL REFERENCE LIBRARY for continuing medical education whereas residents used the system primarily for problem-solving, and
3) a general attitudinal ambivalence was directed toward the CLINICAL REFERENCE LIBRARY by the nurses.

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CHAPTER I

THE PROBLEM

The scientific work of antiquity was disseminated by word of mouth, by correspondence or by laborious copying of manuscripts by scribes. Scholarly activities were restricted to a few centers where extensive collections of manuscripts were available. The development of the printing press in the fifteenth century revolutionized the dissemination of knowledge. Today, the computer and its application in information storage and retrieval and data acquisition and analysis has created an equal or perhaps a greater revolution than the invention of the printing press (34).

THE KNOWLEDGE EXPLOSION

During the past 50 years, there have been rapid advances in medicine and its allied sciences. Consequently, there has been a phenomenal increase in technical and scientific knowledge (52). The 1933 edition of Cecil's Textbook of Medicine is one such illustration of the progress made in the last 50 years (12). There was no effective treatment for bacterial mycobacterial or fungal diseases; thus, bacterial endocarditis, miliary tuberculosis and cryptococcal meningitis were fatal diseases. Adrenal steroids had not been discovered. Diuretics were not available for the management of heart failure, nor were there any drugs for the control of hypertension. Anticoagulants had not yet been introduced. The role of lymphocytes, immune complexes and complement had not been elucidated. Discussion of "acidosis" and "alkalosis" were based on only one clinical test - i.e. measurement of the carbon dioxide combining power of the blood. Surgical removal of tonsils and adenoids were ethusiastically recommended: "The beneficial results...are so great and so prompt that unless there is a distinct

reason for its omission, it is folly to wait for spontaneous shrinking ..." (12). Mechanical ventilation, renal dialysis, extracorporeal membrane oxygenation, cardioversion, and cardiac pacing were unknown. Bleeding peptic ulcer was managed by the application of an icepack to the epigastrium, complete starvation, morphine hypodermically, and water, glucose and soda by rectal drip. Blood banks were not available and the transfusion of a single unit of blood was a formidable procedure. Diagnostic procedures in clinical biochemistry and immunology, which are now commonplace, had not yet come into use. Investigative and diagnostic procedures such as angiography, sonography, computerized tomography and fiberoptic endoscopy were unknown.

More recently, medicine has seen "cures" in childhood leukemia, computerized tomography, mass production of insulin and growth hormone using recombinant DNA technology, in utero surgical repair of congenital anomalies, laser microsurgery, radionuclide imaging, reimplantation of traumatically amputated extremities and digits, the development of artificial skin for burn victims and the transplantation of body organs (corneas, kidneys, heart, bone).

Because medical knowledge is continually changing and expanding, the number of medical problems encountered are also increasing. The reasons for this are many: surgical intervention in the very young and the elderly, the debilitated and poor-risk patients; the use of steroids, chemotherapy and irradiation predispose patients to complications and disease processes that were unknown half a century ago; the widespread use of antimicrobials and the common practice of polypharmacy are not without adverse effects. Mass casualties and multiple trauma are common events in today's society. Respiratory

failure, septic shock and chronic renal failure are therefore diseases of modern medicine.

During the past decade, advances in medicine have lead to a deluge of information and technology, making the contempory medical care system more complex, more information-dependent, and more technology-oriented. The critically ill or injured patient also requires more specialized care. Changes in the concepts and methods of care of these patients reflect not only the development of new therapeutic measures and the understanding of various disease processes, but also a more aggressive attitude by physicians toward therapy and the availability of equipment for monitoring and resuscitation. This combination of new attitudes, methods, and equipment is exemplified by the intensive care unit (ICU) and by specialty units in tertiary care centers. Regardless of how a patient gets into serious life-threatening difficulty, every critically ill patient enters a "final common pathway" of multisystem failure. Consequently, multidisciplinary teams - including medical and surgical specialists, anethestists, nurse specialists, and allied technical personnel - are required to care for the critically ill.

KNOWLEDGE ACQUISITION IN MEDICINE

To the practicing clinician, the acquisition of medical knowledge is a life-long process which includes not only the formal education at the undergraduate and postgraduate (residency) medical training levels, but also the more informal education accompanying active patient care. The amount of knowledge that is needed to address all medical problems has far surpassed the ability of any one physician to consistently retain, recall and apply this information (6). Although this informa-

tion exists in various forms (textbooks, journals, informal discussions, etc), it is usually not available in a manner readily accessible to the physician.

How then do physicians keep abreast of medical information? Continuing medical education (CME), initially implemented on a voluntary basis, is now a requirement for reregistration by many state medical licensing boards and for recertification by some specialty boards in the United States (61). Mandatory continuing medical education programs do not exist in Canada (5). CME and assessment can be in the form of accredited post-graduate courses and workshops (41), computer-based education (CBE) (49), and home study CME courses (47, 65).

Scientific congresses, informal personal conversations, professional consultation, rounds, seminars and journal clubs are valuable adjuvants to the educational process. Symposia and discussions are sometimes tape- or video-recorded and subsequently published e.g. Audio-Digest and Medifacts. The circulation of manuscripts within the academic environment is a method whereby interested colleagues have requested that they "be kept up to date with developments in your lab". Much useful information is conveyed by leaflets, brochures, and newsletters produced by pharmaceutical manufacturers, suppliers and non-profit organizations e.g. MEDICAL LETTER, CLINICAL SYMPOSIA and CLINICAL CONSULTATIONS.

Textbooks, journals and periodicals are the most frequently cited means of obtaining information to satisfy a particular need, whether it be for problem-solving, continuing medical education or recreation (46). Library services include the borrowing of books, audio-visual materials, telephone enquiry services (9) and photocopying services. Indexing

services such as INDEX MEDICUS and CITATION INDEX are printed monthly and updated annually.

Computerized information networks such as MEDLARS (Medical Literature Analysis and Retrieval System) and MEDLINE (MEDLARS On-Line) are the most complex and extensive medical information retrieval systems (39).

The problem of keeping abreast of new medical information is even more pronounced in the intensive care unit (ICU) as exemplified in the following section.

MEDICAL INFORMATION IN THE INTENSIVE CARE UNIT

For the purpose of clarity, a brief definition of some terms with respect to patient management is in order. In medicine many terms are used interchangeably to describe the cognitive process. "Problem-solving" is the process of developing a differential diagnosis and ultimately arriving at a final working diagnosis and eventually a correct diagnosis. The term "medical inquiry" focuses on the data-gathering or evaluative aspect of this process. The terms "clinical judgment" or "medical decision-making" focus on the decision-making component. For these reasons, "clinical reasoning" has been chosen as the term to encompass all the cognitive skills implied in patient evaluation and management (4).

At the present time, a clinician working in the intensive care unit uses a combination of intuitive skills and knowledge acquired through experience. In times of life-threatening crises the traditional sequence of detailed enquiry for diagnosis, investigation, confirmation, and therapy is unsatisfactory (4). (Indeed, even in nonlife-threatening

situations it is unsatisfactory. There is an incongruence between how people are taught and/or trained to resolve problems and how it is actually done by practicing physicians. But this process is even more important in the intensive care unit.) Priorities must be established and therapy must be set into motion if life-threatening and life-saving measures are to be effective. Thus, clinical reasoning and therapeutic intervention in the intensive care unit proceed in parallel rather than in followup to a diagnostic study.

Critically ill patients often have multiple problems on admission and during their stay in the intensive care unit may develop one or more problems. This is illustrated in the following typical case history.

> A 38 year old, morbidly obese female underwent jejunoileal bypass and was lost to followup. Progressive and unremitting weight loss ensued and at eleven months her weight had fallen from 193 to 97 kg. She was admitted to hospital complaining of lethargy and circumoral paresthesia. Laboratory investigation revealed a markedly depleted serum albumin, hypocalcemia, hypokalemia and a depressed total lymphocyte count. The surgeon elected to interpose an additional 15 cm of ileum. The patient was discharged on the fifth postoperative day after an "unremarkable" course despite a low grade fever which was attributed to mild atelectasis.
>
> Three days later, she was readmitted with severe abdominal pain, nausea and vomiting. She was afebrile. Radiographs revealed marked gastric dilatation. Laboratory investigation revealed a moderate leukocytosis with a "shift

to the left". She was initially treated with nasogastric suction and intravenous fluids but the nasogastric tube was removed on the third day and her diet advanced. On the seventh day, the patient suddenly developed profound hypotension and a rigid abdomen.

After the administration of large volumes of intravenous fluids, steroids and antibiotics she underwent an emergency laparotomy which revealed a disrupted anastomosis and extensive intraabdominal soilage. Peritoneal lavage was performed and an ileostomy and mucocutaneous fistual were created. She was then transferred to the intensive care unit.

Despite aggressive management, the patient went on to develop respiratory failure, renal failure, gastrointestinal hemorrhage, wound dehiscence and systemic candidemia. She died on the fourtieth postoperative day.

In summary, this patient presented with signs and symptoms of malnutrition following an intestinal bypass procedure. Had this patient's markedly malnourished state been corrected before the elective operation the subsequent events could well have been avoided. Because of a delay in the diagnosis of intraabdominal sepsis, she developed bacteremic shock and its sequelae. Intensive postoperative therapy with wide spectrum antibiotics, mechanical ventilation, hemodialysis and hyperalimentation were unsuccessful.

This example illustrates the need for adequate

information in the ICU: What is the course of this disease? What are the complications? What is the optimal form of therapy? What therapeutic options are contraindicated and why? What are the complications of therapy and how can they be prevented? What is the patient's prognosis? Can the prognosis be altered and, if so, how?

The health care professional may or may not have this information. Information sources in the intensive care unit are variable. Human resources beyond that of the resident-on-call are generally limited to the chief resident and/or attending staff. The supervisor may not be readily available. Fellow residents, nurses and other paramedical personnel are limited sources of information. Textbooks are costly, easily misplaced and, if succinct, readable, and portable, are often misappropriated. The hospital library is not usually in close proximity to the intensive unit and even if it is accessible, there is no guarantee that the information will be available. Thus, the major drawback is that there is no one up-to-date, clinically relevant information source that is available around the clock and located in close proximity to the bedside.

No one physician knows all the information necessary to practise all aspects of medicine. Human memory is often imperfect and is further restricted by fatigue, stress and a demanding work schedule. Attempts to overcome these deficiencies have lead to the development of computer-based consultation systems. In theory, these systems have rapid, accurate and infinite processing capabilities, provide an immediate source of information, are availablle 24 hours-a-day, are located physically within the intensive care unit, and serve to reinforce concepts and principles of patient management and/or disease

processes. Unfortunately, most systems developed to date are not ICU-directed or -oriented.

STATEMENT OF THE PROBLEM

In an effort to provide the health care professionals in the intensive care unit with readily available and systematic information, a computer-based clinical information system (CLINICAL REFERENCE LIBRARY) was designed. This bedside system contains information about common problems encountered in the ICU: the criteria for intubation and assisted ventilation; the complications of a tracheostomy; the pathophysiology of acid-base abnormalities; the management of a patient with a pulmonary embolus, or aspiration pneumonia or spectic shock; drug interaction; pediatric medications; the rational use of antimicrobials; the management of the head-injured patient; the insertion of a Swan-Ganz catheter and the interpretation of the various wave forms; the pathophysiology of starvation and the implementation of hyperalimentation; and the interpretation and treatment of cardiac arrhythmias.

Two specific questions were asked:

1) Would this bedside information system be used by clinicians, graduate and undergraduate physicians-in-training, nurses, and other paramedical personnel?
2) Would this computer-based clinical information system be an effective teaching tool?

AN OVERVIEW OF THE CONTENTS

The present thesis describes the development and evaluation of a

computer-based clinical information system in the intensive care unit. In this chapter, the conceptual need for the development of such a system is discussed. The application of computers in medicine and the use of computer-based medical information systems are described in Chapter II. This is followed by a description of the intensive care delivery system at the University of Alberta in Chapter III and the description of the HP 5600A COMPUTERIZED PATIENT DATA MANAGEMENT SYSTEM in Chapter IV. Chapter V provides a detailed summary of the development of the CLINICAL REFERENCE LIBRARY. In Chapter VI the methodology of evaluation is described. The analysis and results of participant data and the results of questionaires about the CLINICAL REFERENCE LIBRARY are presented in Chapter VII. Discussion of the data and recommendations for further research and development are presented in Chapter VIII.

CHAPTER II

REVIEW OF THE LITERATURE

In this chapter, literature related to the role of computers in medicine and clinical medical information science will be presented. The chapter is divided into five parts. The first part is a brief introduction about the history of computers. This is followed in part two with a summary of the application of computers in medicine. A review of computer-based information systems is presented in part three. The impact of computers on clinical medical information science is presented in part four. The chapter is summarized in part five.

INTRODUCTION

The first "computer" devices, the oriental abacus and the occidental Antikythera device, were in use over 2000 years ago. The development of computers lay dormant until Pascal's invention of a small mechanical adding machine in the seventeenth century. The first operational automatic computer was introduced in 1944. Digital computers were virtually unknown in medicine in the 1950's (22).

THE ROLE OF COMPUTERS IN MEDICINE

Progressive improvements in the manufacturing of integrated circuits has reduced the size and cost of many electronic devices. The relative inexpensiveness and miniturization of computers have led to the development of many new medical technologies. One notable example is the computerized tomography scanner which produces precise images of anatomical cross-sections with no discomfort to the patient, thereby dramatically reducing the use of invasive techniques.

Computer-Assisted Data Acquisition

Computers have been programmed to record and analyze electrocardiograms (EKGs) in real-time (51), to assist in cardiac catheterization (35), to take medical histories and to enter data in a variety of clinical settings such as radiology (53), intensive care medicine (73), obstetrics and gynecology (23), and ophthalmology (42).

Computer-Assisted Diagnosis

Automated systems can assist a physician in medical diagnosis (8). This is of particular value where speed of evaluation is crucial, as in the management of the critically ill patient. In such applications, computers offer easy access to large quantities of medical information and an ability to analyze multiple variables simultaneously. Computer-assisted diagnosis has been successfully applied in the analysis of EKG arrhythmias (51), vectorcardiography (1), and electrolyte and acid-base disorders (8).

Computers and Medical Therapy

Computer-based devices can assist physicians in decisions relating to therapy: automated infusion pumps (7), measurement of blood volume, urine flow and blood lactate (70), hemodialysis (56), drug interaction (3) and neurostimulation (32).

Monitoring/Control of Physiological Systems

Monitoring devices presently found in the intensive care unit activate alarms to summon the medical staff when a patient needs special attention. Devices have been developed for in-hospital control of blood

pressure (30), and fluid resuscitation and control of ventilation using closed-loop (feedback) technology (71). At present, the development of closed-loop, implantable devices for long-term use in control of blood pressure or blood sugar is hampered by a lack of miniturized sensors capable of functioning in vivo for extended periods of time (21).

A variety of microprocessor-based monitors are available which do not attempt to control the patient's physiology. Hospital-based systems include fetal (36) and obstetrical monitoring (23), and blood pressure, EKG and respiratory monitoring during anesthesia (27). Cardiovascular telemetry (38) and EKG monitoring (69) are examples of out-patient monitoring.

Computers and the Handicapped

Microprocessor-based prostheses can control crude motorized artificial hands by analyzing myoelectric signals arising from forearm stumps (24). Microcomputers have been used in the development of hearing aids and sound perception (20), synthetic voice (28), voice-controlled wheel chairs (13), and writing aids for the motor handicapped (50).

Computers and Hospital Information Systems

Computers have found application in the management of patient information in physicians' offices (10), emergency departments (2), and out-patient departments (44). CLINFO (67), COSTAR (57), and COMTRAC (37) are examples of successful hospital laboratory and administration information systems.

Computers in Medical Education and Assessment

Computers are widely used throughout the continuum of medical education and assessment (14). It has been stated that they allow a much wider range of individualized responses in tutorial sessions, a greater degree of "instructor" responsiveness to individual background and needs, and more immediate feedback in the teaching or training purposes. Computers also provide a more objective testing mechanism for assessing clinical problem-solving abilities (14).

TICCIT (Time-Shared Interactive Computer-Controlled Information) and PLATO (Programmed Logic for Automated Teaching Operation) are exclusive educational systems (14). The latter is more popular. PLATO provides interactive, self-paced instruction for large numbers of students. Lesson material is presented on a video display terminal and may consist of text, drawings, graphs and color photographs. Students interact with the material through a special keyboard that closely resembles a typewriter keyboard. Students receive instruction reinforcement of correct work and assistance where they are having difficulty. The users of PLATO range from grade school students learning reading and mathematics to graduate students in the medical sciences.

The Faculty of Medicine at the University of Alberta has conducted undergraduate teaching of cardiology using PLATO. Instruction is given in heart sounds and murmurs, electrocardiography, common valvular lesions and common congenital problems. There are a number of test cases and examinations have been conducted to determine user performance (33).

The College of Medicine at Ohio State University employs an

optional independent study program (ISP) for completing the basic science portion of the Doctor of Medicine curriculum. In contrast to the traditional lecture-discussion program in which students progress through a standard content sequence in a predetermined, fixed amount of time, the independent study program follows a self-study format which allows progress at independent rates (14).

Several different models of computer-based simulations are used for educational assessment. The Royal College of Physicians and Surgeons of Canada has used Computerized Patient Management Problems (CPMPs) in their Pediatric Fellowship Examination process to test the ability of pediatric candidates to manage patients (63, 66). CPMPs were also used between 1974-79 as part of the examination process for approximately 110 final year medical undergraduates at the University of Alberta (14). CPMPs have been incorporated into a self-assessment package that is available to fellows of the Royal College during the time of the College's annual meeting (14).

The Computer-Based Examination (CBX) Project of the American Board of Internal Medicine and the National Board of Medical Examiners is based on a computer simulation of a patient with a given disease or diseases (26, 58). Laboratory tests, medical procedures or consultations, and drug therapies interact with the patient's disease in a time sequence similar to one occuring in real life. By simulating the effect of physician action on the patient, and by adjusting the patient's status accordingly, the computer model provides an almost life-like, dynamic simulation of the patient-physician encounter.

The MERIT (Model for Evaluation and Recertfication through Individualized Testing) system was designed to incorporate individualized

evaluations of a candidate's performance in patient care as a major part of the recertification procedure for the American Board of Internal Medicine (14). A computer-assisted simulation of the clinical patient encounter requires that the examinee use natural language mode to resolve the problems of the simulated patient. No direction is provided, such as multiple choice lists, to resolve the problem(s).

COMPUTERS AND MEDICAL INFORMATION SCIENCE

Osler is said to have cited ordered and logical analysis as the key to good patient management (68). Today's physicians are unable to consistantly perform this analysis and synthesis, despite their improved training, because of the enormous surge of knowledge about disease processes and therapeutics in the past 30 years and the inability to bring this information to the clinician in a systematic manner at the time and place where it can best be utilized. Other complicating factors include many more and sophisticated diagnostic tests and numerous therapeutic possibilities; not only are there many more facts to be applied to patients' problems, but many more facts to be learned as well. The end result has been a conscious effort by the physician to focus his/her sphere of responsibility and interest through specialization, such that only a portion of the patient's problems can be handled by any one individual.

Even though computers have been applied to various aspects of medicine, they have only recently begun to influence the clinical practice of medicine (25). Patient management requires numerous clinical decisions which are dependent on the ability to systematically and logically process increasing amounts of information. The computer

can influence this process by applying sophisticated and widely dispersed resources more effectively and by assisting in the basic decision-making process.

Recent studies support the idea that better patient management can result from computer-assisted strategy applied during the clinical patient management process. McDonald has structured a feedback mechanism in the form of computer-generated recommendations on relatively specific decisions regarding individual patient-management situations (43). Physicians took action on 51 percent of the recommendations when these were communicated in the form of cues, and on only 22 percent of the equivalent set when left to their own devices, both before and after receiving feedback. After documenting several additional studies where various clinical cues were overlooked, McDonald concluded that limitations in physicians' ability to react consistantly and appropriately to a given set of stimuli in the clinical setting exist by virtue of being human, a fact that cannot be ignored.

de Dombal has demonstrated that the accuracy of clinical decisions supported by computer logic were superior to the clinicians' working independently on 600 cases of patients complaining of acute abdominal symptoms (15, 16). A structured information-acquisition process with feedback to the clinicians was then instituted for the next 552 acute abdomen cases which presented at the St. James Hospital in Leeds, England. Perforation of the appendix before surgery dropped from 36 percent to 6 percent, and the "negative" laparotomy rate fell from 20 percent to 7 percent. When structured questions and feedback were removed, the decision-making of the clinicians regressed toward previous levels (15, 16). Subsequent studies by the same group in 1974 and 1975

corroborated these findings (17).

Computer-based consultation systems range from those used in specific disease states or problem areas to those used for more general purposes. A number of these systems are summarized below.

Duke University Cardiovascular Information System

This system provides physicians with a large data base about clinical experiences with coronary artery disease (55). The data describe outcomes of patients with various sets of attributes. The patient attributes, laboratory and physical findings, history and outcome of a large number of patients are stored in a computer, which then classifies the information. When attributes of a new patient are entered, the computer searches all patient records, and those which fit the criteria are then separated into a subgroup for further on-line queries. Rosati and his group have likened this activity to a "dynamic, living computerized medical textbook". It has the advantage of giving the physician more accurate and unbiased information based on a large number of patients (55).

Electrolyte and Acid-Base Consultation System

Bleich has constructed a computer-based consultation program to help physicians manage patients with electrolyte and acid-base disorders (8). The program directs a dialog in which the user enters clinical and laboratory information. On the basis of the abnormalities detected, the program "asks" questions to further characterize the electrolyte and acid-base distrubance(s). During or after the completion of the dialog, an evaluative note is produced that contains a list of diagnostic

possibilities, an explanation of underlying pathophysiology, therapeutic recommendations, precautionary measures, suggestions for further studies, and references to the medical literature.

HELP

HELP (Health Evaluation through Logical Processing) is a complex diagnostic management support system at the Latter Day Saints Hospital in Salt Lake City, Utah (19). A variety of findings on symptoms data and patient status information are incorporated into the system (e.g. laboratory tests, blood gas analysis, medical record abstracts, etc). Decision logic utilizes a variety of statistical techiques to determine probabilities for certain diagnoses or treatment selections based on the historical data base. In addition, the system provides warning of patient conditions that may require intervention.

A survey conducted by Batelle Laboratories, an independent evaluation group, revealed a positive attitude among physicians toward the HELP system. The highest proportion of physicians that were very enthusiastic about the system were specialists in surgery and internal medicine (52).

INTERNIST-I

INTERNIST-I was designed at the University of Pittsburg as a computer-based diagnostic system for problems in internal medicine (40). It is based on assigning rough estimates of the likelihood of the association of a disease, given a particular finding, and a similar estimate of the likelihood of a finding, given a particular disease. The current knowledge base includes roughly 70-75 percent of the major

diagnoses in internal medicine (48). INTERNIST-I represents an attempt to model, within a computer program, the thinking processes that a clinician uses to evaluate a case and make a diagnosis. It is not a model based on probabilities in the true statistical sense and therefore, is subject to the individual perspective brought to the model.

The system attempts to mimic the diagnostic behavior of the "excellent clinician". Miller et al attempted to document the strengths and weaknesses of the program (48). Its performance on a series of 19 clinicopathological exercises (Case Records of the Massachusetts General Hospital) published in the New England Journal of Medicine was qualitatively similar to that of hospital clinicans but inferior to that of case discussants. The evaluation demonstrated that the present form of the program is not sufficiently reliable for clinical applications. Specific deficiences that must be overcome include:

1) the program's inability to reason automatically or temporally
2) its inability to construct differential diagnoses spanning multiple problem areas
3) its occasional attribution of findings to improper causes, and
4) its inability to explain its "thinking".

The Indiana University Medical Center Computer Reminders System

This system is based on the assumption that the physician must apply a few simple categorical rules to a few items of information many times (43, 44). Using a very simple computer language, designed specifically for this system, the physician writes the rules he/she wishes applied to the data and then lets the computer repeatedly apply them. The system provides reminders for a large percentage of simple

clinical decisions; it assures that the baseline screening tests have been done, checks that abnormal test findings are examined further, and assumes that treatments are followed with appropriate measures. The system occasionally "suggests" diagnoses when a particular abnormality is evident, but more often suggests treatments that might correct a pattern of abnormalities.

PROMIS

The Problem Oriented Medical Information System at the University of Vermont was developed by Weed and his coworkers to facilitate the organization of medical care, to make the logic of health care decision explicit, and to decrease the user's reliance on memory (14). Although not originally designed to be a computer-based consultation system, it is capable of presenting structured reference information (31).

Data is organized by patient problems. The computer record is structured around four phases of medical action:

1) an initial data base on each patient, including medical history and physical examination
2) a list of the patient's problems
3) diagnostic and treatment plans for each problem, and
4) progress notes on each problem indicating how the patient is progressing during therapy.

Except for the initial data base every entry into the computer record is associated with a particular problem of the patient. By structuring the medical record in this way, all patient information is logically organized for review.

A variety of diagnostic and management protocols based on common or

potentially serious medical problems (e.g. hypertension, anemia, postoperative fever, and cardiac arrhythmias) encountered on a gynecology service have also been developed. This information is available to the health care professional via a touch screen cathode terminal. Each protocol consists of hundreds of individual displays. The content is routinely updated by a committee of recognized medical authorities. The updating service involves comparing the information contained in articles from selected medical journals with the computerized medical displays on a given topic.

MYCIN

The MYCIN system at Stanford University is an interactive computer program which uses the clinical decision criteria of experts to advise physicians who request advice regarding selection of appropriate antimicrobial therapy for hospital patients with bacterial infections (58). The system uses information provided by the physician (e.g. signs, symptoms, laboratory data, and normal and pathogenic flora of nonsterile body sites), together with its own knowledge base, to determine organism significance, organism identification, and appropriate therapy selection. Through interactive prompting the user may also request alternate therapy, recommendations, explanations of MYCIN's reasoning processes and justifications of its recommendations.

Formal evaluation of the program's therapy recommendations meet with Stanford's experts' standards of accepted practice 90% of the time with some variation noted both among individual experts and between Stanford experts and others (76).

CARE

The CARE (Clinical Assessment, Research and Educational) system is a time-shared computer-based physiologic monitoring system which is available nation-wide in the United States (60). It is designed to be a management and education aid for the treatment of critically ill surgical patients.

The user is assisted in making the best critical care decisions through computer-directed, interactive prompting. "Living textbook" programs present therapeutic cautions and recommendations based on the initial major problem and underlying factors. References to relevant medical literature are made were appropriate.

In a nonrandomized, uncontrolled prospective analysis of all surgical ICU mortality, Siegel concluded that "the application of the computer-based CARE system for physiologic assessment will have an additive beneficial effect on surgical mortality, when used in the setting of a structured ICU teaching service where the data can be appreciated in a timely fashion and used as important information by which to modify therapeutic decision making" (61). Statistically significant reductions in ICU mortality were demonstrated in major traumatic injury, in surgical patients with complictions of gastrointestinal disease and major noncardiac thoracic surgical procedures. There was also a reduction in the mean surgical ICU length of stay for survivors of 0.82 days and therefore of estimated cost of care. Whether the CARE system was directly or indirectly responsible for these findings is open to speculation. Motivation of the resident and nursing staff and organization of the teaching service are factors that obviously influence the success of the CARE system but attempts to

evaluate these aspects have not been made.

HOISS

House Officer Information and Scheduling System (HOISS) is a simple computer-based problem oriented information system designed to assist physicians-in-training with the investigation and treatment of acute medical problems (74). It consists of a file of information on 79 common medical problems ranging from raised alkaline phosphatase to weight loss. The information on each problem is divided into general information, investigative procedures, and treatment.

Using information provided by the clinician, HOISS produces an outline of each of the patient's clinical problems. Hard copies of these outlines are then placed in the patient's record and are used as a guide to collect information about his/her clinical state.

Evaluation of the system involved tabulation of 13 clinicians' responses to a 22-part questionaire (75). All the users found the system helpful in the managment of patients' problems, felt that patient care was improved and that their knowledge about the investigation of acute medical problems had increased. No attempts were made to objectively determine knowledge acquisition or the effect of HOISS on patient care.

Young also compared the managment of similar groups of patients cared for with or without the help of HOISS (73). He concluded that HOISS increased the consistency of investigation of patients with similar problems. Indeed, HOISS has its greatest influence on less common conditions.

THE IMPACT OF COMPUTER TECHNOLOGY ON CLINICAL MEDICAL INFORMATION SCIENCE

"Computer technology and information science have been applied with recognized success to many areas of modern scientific and industrial development and have been a major determinant in accelerated pace of advances in physical and basic sciences. However, critical applications in the area of medical and health care, although frequently supposed and increasingly attempted, have been disappointing in their impact on the health care system" (29). Freidman and Gustafson (25) have outlined the probable reasons for the failure of computer technology to gain acceptance among physicians and to influence the day-to-day management of patient care:

1) The physician has not yet been provided with computer systems that exceed his/her own capabilities. In medicine the measure of success is diagnostic accuracy equal to that of a skilled clinician, accurate EKG analysis, or historical data acquisition which saves the physician time. Many physicians feel that computers are professionally threatening to their role as clinicians and will only serve to further dehumanize the health care system.
2) The physician-computer interaction is unnatural and can be tedious and time-consuming. Computer systems require physicians and other health care professionals to work in a manner which is alien to their normal practice and/or training.
3) A significant positive impact on patient care by successful utilization of computer technology on medicine and health care has yet to be demonstrated. The initial construction and

implementation of a computer system is expensive, time-consuming and may require reorganization and/or retraining of hospital personnel.

4) There is a disarray of computer languages and computer systems that prevents the transfer of applications from one institution to another. Unlike business and industry, most computer systems are not compatible or interchangeable.

5) Research has not been conducted in satisfactory manner. The majority of projects in the area of computer applications to medicine subsequently prove to be impractical, too expensive, or unacceptable. And yet researchers continue to duplicate previous efforts or mistakes. A survey of 32 computer applications in medicine published during a 5-year period revealed that 51 percent of these projects had been abandoned or temporarily halted when the initial research funds were exhausted (25). This occurred despite the fact that the majority (63 percent) of the projects had lived up to their author's expectations. In almost every case the reason for abandonment was that the project was not cost-effective. In only 19 percent of cases did the authors of the programs report that they were in routine use.

These reasons are at least part of the explanation for the lack of widespread acceptance of clinical computer systems. Little information is available on the evaluation of such systems. This thesis describes the development and evaluation of a computer-based bedside information system in the intensive care unit. The system is called the CLINICAL REFERENCE LIBRARY.

SUMMARY

Literature related to the role of computers in medicine was presented in this chapter. Major clinical information systems available today were discussed. The lack of ICU-directed or -oriented clinical information systems was emphasized. The reasons for the failure of computer technology to gain acceptance within the medical community were also summarized. The next chapter describes the environment in which the CLINICAL REFERENCE LIBRARY was tested.

CHAPTER III

THE INTENSIVE CARE DELIVERY SYSTEM

This chapter is divided into three parts. The development of the specialty of critical care medicine and the concept of the intensive care unit are described in part one. Part two is devoted to the description of the intensive care delivery system at the University of Alberta. The organization of the intensive care unit and the structure of the teaching services are also described. The chapter is summarized in part three.

INTRODUCTION

The techniques available today for preserving vital functions in the critically ill or injured patient were largely unknown before 1950 when a conservative approach characterized the management of this group of patients. It was not until the 1960's that intubation and mechanical ventilation, hemodialysis, volume repletion guided by central venous pressure and cardiac resuscitation by the routine use of defibrillators and pacemakers came into general use. Progress in the field has been accelerated by giant strides in technology.

The intensive care unit (ICU) provides personnel and facilities that make it possible to bring the full benefits of these and other techniques to the critically ill or injured patient (70). The physician who is called to the bedside is confronted by an array of monitors and sophisticated equipment. Although the traditional techniques of noninvasive diagnosis are essential for competent understanding of the patient's clinical status they do not suffice. In times of crisis, however, specific measurements of major physiologic distrubances and quantitation of the severity of the vital defects are needed.

Practical examples may be cited to illustrate the implications of

expanded concepts of diagnosis and monitoring. Auscultatory changes in the chest, peripheral cyanosis and other physical findings are likely to be supplementary rather than primary indicators of the patient's physiological state. The physician or nurse must be prepared to obtain arterial blood samples for analysis of blood gases and blood pH. Alterations in the cardiac rhythm can be detected by cardiac auscultation, but they are interpreted most appropriately on the basis of the electrocardiogram, especially in relation to the central arterial pulses. Neck vein distention and hepatic enlargement are not sensitive signs of limited cardiac competence in the critically ill patient; the clinician may be called on to insert a catheter into the right heart, and into the pulmonary artery to obtain pertinent information on ventricular function which is then used to determine clinical management. Guided by a combination of clinical, physiologic and laboratory findings, the physician working in the intensive care unit is prepared to insert an endoctracheal tube and to institute mechanical ventilation. In instances of acute circulatory failure, he increases the intravascular volume by "fluid challenging", at the same time, guarding against the risk of pulmonary edema and potentially fatal acute respiratory failure. He supports myocardial function by the administration of inotropic agents such as dopamine or by mechanical assist devices such as the intraaortic balloon pump. If a life-threatening alteration in cardiac rhythm presents itself, he must be prepared to use either pharmacologic or electric methods by which an effective rhythm is restored. In summary, his competence crosses traditional specialty lines.

THE UNIVERSITY OF ALBERTA HOSPITALS INTENSIVE CARE DELIVERY SYSTEM

Organization

The Univerity Hospital is the primary teaching hospital of the Faculty of Medicine at the University of Alberta. It serves as the major referral institution for Northern Alberta. The Royal Alexandra Hospital is a center for secondary and tertiary care and is also affiliated with the Faculty of Medicine.

The University Hospital ICU (Station 68) is a 10-bed unit capable of providing full vital systems monitoring and organ support. It is not a postoperative recovery room or a coronary care unit. It operates as a "closed unit" in that all patients are transferred to the care of the Director or one of the Associate Directors and are cared for by the ICU team. This multidisciplinary team consists of a Chief Resident, three or four Rotating Residents (secunded from Internal Medicine, Anesthesia, and General Surgery and the other surgical subspecialties), a Charge Nurse, Nurse Specialists in Critical Care, Respiratory Technologists, Chest Physiotherapists and a Life Support Technician.

The ICU at the Royal Alexandra Hospital (Station 23) is an 8-bed general systems failure unit under the direction of a Director and a Co-director. It is neither a coronary care unit nor a general recovery room although postoperative craniotomy cases are routinely admitted. It is also a "closed unit". The multidisciplinary team is identical to that of the University Hospital ICU except that there is no Life Support Technician.

The ICU team is responsible for all aspects of care of the critically ill or injured patient. Both units have facilities for

monitoring and support, including mechanical ventilation, flow-directed balloon-tipped catheter monitoring, fiberoptic bronchoscopy, intracranial pressure monitoring, total parenteral and enteral nutrition, peritoneal dialysis, and cardiac pacing. The University Hospital ICU has facilities for hemodialysis, hemoperfusion, plasmaphoresis, and external counterpulsation.

There are two major differences in the organization of the University Hospital ICU and the Royal Alexandra Hospital ICU: the former conducts an air ambulance service for Northern Alberta while the latter does not routinely care for patients under the age of sixteen years.

The ICU Teaching Service

The intensive care unit plays an important role in undergraduate and postgraduate (residency) training. Three or four second- or third-year residents are assigned to the intensive care unit for 2- to 3-month overlapping rotations. These residents have no other patient care responsibilities. All residents are assigned to the unit during the day and one resident remains on-call in the unit each night. Although the overall responsibility for and direction of patient care is that of the Director or one of the Associate Directors (or Co-director), the details of patient management are the responsibility of the Chief Resident and the ICU Residents. All orders, with appropriate supervision, are written by the ICU housestaff. The ultimate authority and responsibility for changes in therapy as recommended by consultants not associated with the ICU is that of the Director or one of his associates.

Decisions reserved for the Chief Resident or the Directors are

concerned with the appropriate utilization of ICU resources, including triage and the institution and the countermanding of therapeutic decisions which are contrary to general ICU policy or are detrimental to patient care.

Medical students are usually relegated to the role of observers but are encouraged to participate in the daily routine of the intensive care unit as much as possible.

Bedside rounds are conducted at least twice daily. Weekly service rounds are conducted by the resident staff and medical students. Didactic sessions are held daily and are presented by the residents, attending staff or visiting professors.

Nursing inservice rounds are held at each hospital on a regular basis. Even though attendance is mandatory at the Royal Alexandra Hospital, attendance at such sessions are about equal.

The total number of patients admitted to each ICU each year is in the order of 450. The mean ICU stay is about 7 days with a median of 3.5 days. Patients come for medical and surgical services in approximately equal numbers.

SUMMARY

In this chapter the intensive care delivery system at the University of Alberta was described. The next chapter deals with the HP 5600A Computerized Patient Data Management System.

CHAPTER IV

THE HP 5600A COMPUTERIZED PATIENT DATA MANAGEMENT SYSTEM

In this chapter four topics are discussed. The first part is a brief overview of the capabilities of the HP 5600A Patient Data Management System: the patient monitoring system with which the CLINICAL REFERENCE LIBRARY is intimately associated. The second part describes the system hardware. Operation of the CLINICAL REFERENCE LIBRARY from the bedside is emphasized. A brief description of the software including the CLINICAL REFERENCE LIBRARY is presented in the third part. The chapter is summarized in part four.

INTRODUCTION

The HP 5600A Patient Data Management System (PDMS) was installed in the University Hospital ICU in November 1980. The initial purchase price was $425,000. Operating and maintenance costs are about $30,000 a year. Operation of the system is the responsibility of the Department of Information Systems.

THe PDMS handles a wide spectrum of patient data from admission through diagnosis and treatment, to discharge and followup. It automatically logs each patient's vital signs, accepts and stores staff notes and manually-entered laboratory data, produces a variety of displays of data in tabular and trend form, and prints hard copies of the displays as well as other reports on demand.

THE HARDWARE

Conceptually, the PDMS consists of a medical subsystem and a computer subsystem. The medical subsystem consists of bedside monitoring equipment, medical data terminals and the hardware necessary to interface the monitors and terminals to the computer. The 2113A

computer and the equipment peripheral to it comprise the computer subsystem (Plate 1). The computer utilizes a HP 7920 disc drive (capacity 50 Mbytes) and drives a HP 2631A character printer.

The beside monitors have direct cabling to the central nursing station and to the computer's analog-digital converter. One terminal can be shared by several beds. Alpha-numeric displays with attached keyboards are located in the computer room (Plate 1) and central nursing station (Plate 2) and can be connected to the computer via telephone.

All communication between the user and the PDMS is conducted in natural language mode. There are two basic types of terminals: one, the HP 5671C Video Monitor is located at the bedside and consists of a hand held keyboard (Plate 3) and a 14" video screen (Plate 4); the other, the alpha-numeric terminal (models HP 2645A and HP 2648A) is found in the central nursing station and computer room and consists of a 5 x 10-inch video display in a keyboard similar to that of a standard typewriter (Plate 5). Certain keys on both keyboards are designated as special function keys and are identified by a function name engraved in color above the key's standard character. The purpose of such keys is to provide quick, direct access to specific data displays.

SYSTEM SOFTWARE

Software consists of system programs written in Assembler language and application programs written in FORTRAN.

All data generated during hospitalization in the ICU can be recorded. These include patient admission information, clinical history, physical examination, routinely monitored signals (heart rate, systolic, diastolic, mean arterial and central venous pressures, EKG,

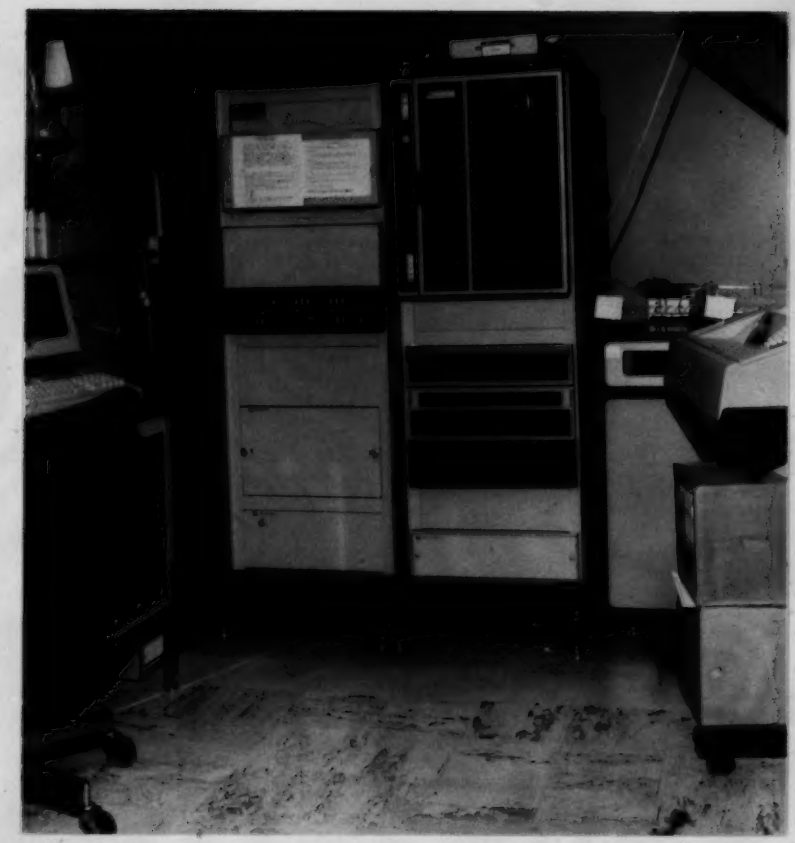

Plate 1:

The 2113A HP Computer and
Peripheral Hardware

Plate 2:

The Central Nursing Station

Plate 3:

The HP 5671C Video Monitor:
Handheld Keyboard

Plate 4:

The HP 5671C Video Monitor:
Video Screen

Plate 5:

The HP 2645A Alpha-Numeric Terminal

and core temperature), physicians' notes and nurses' progress notes, and manually-entered data, including laboatory results, X-ray reports, fluid balance and respiratory information. The complete record of each patient is available for on-line retrieval and hard copies of displays or printed reports are easily obtained.

The ICU team exercises complete control over all aspects of patient monitoring, from selection of the physiological parameters to be monitored and/or trended, to suspension or resumption of monitoring. All control is done dynamically, without stopping or interrupting the system. Data may be stored temporarily or permenantly.

Useful hemodynamic variables (cardiac index, stroke volume index, systemic vascular resistance index, pulmonary vascular resistance index) can be derived from monitored vital signs data and manually-entered data pertinent to a specific cardiac output as determined by the thermal dilution technique.

The Patient Management subsystem enables the user to flip rapidly back and forth through data pertinent to a particular patient's problem, much as one would flip through a patient's chart. The problems relevant to the patient are selected from a master list of problems.

The Drug Infusion Calculator subsystem provides a useful and time-saving means of rapidly calculating the dose or rate of drug infusion. Features of this subsystem include a list of commonly used drugs, a free-form text of recommendations (i.e. information on administration and drug action), a dose meter which graphically illustrates the dose to be administered and warning messages which are displayed to alert the user to toxic doses, erroneous entries or missing information.

The HP Reference Library provides a flexible means for storing

information which may later be recalled for the purpose of references, training or review.

The CLINICAL REFERENCE LIBRARY is available at all terminals including the bedside terminals.

SUMMARY

In this chapter the HP 5600A Computerized Patient Data Management System of which the Clinical Reference Library is intimately associated was described. The next chapter describes the development of the CLINICAL REFERENCE LIBRARY.

CHAPTER V

THE CLINICAL REFERENCE LIBRARY

This chapter which describes the development of the CLINICAL REFERENCE LIBRARY is divided into five parts. Part one describes the conceptual framework and philosophy of the CLINICAL REFERENCE LIBRARY. Part two is devoted to the engineering considerations. Development of the clinical information "modules" is presented in part three. Part four describes the operation of the CLINICAL REFERENCE LIBRARY. The chapter is summarized in part five.

INTRODUCTION

As was mentioned earlier, one of the problems confronting physicians today is that of keeping abreast of medical information. Bernier has stated that the amount of information to be processed and assimilated is well beyond our abilities and that our current retrieval processes are too cumbersome (6). He has quoted Goudsmit: "A modern computer can make a complete literature search in a remarkable short time and overwhelm one with a bibliography that requires a lifetime to read and study."

Bernier has stated that what is needed is a "genuine information retrieval system" (6). That is, one which "answers" questions immediately. He has suggested that the following features be incorporated into such an information retrieval system:

1) the material presented should be indexed
2) the subject matter should be limited to specific areas designated by the user group and should be updated regularly
3) the subject matter should be an abstract of the original work(s)
4) the mechanism by which the information is presented should be

physically accessible at all times, and

5) the information must be available at all times.

These charateristics were incorporated into the CLINICAL REFERENCE LIBRARY.

ENGINEERING CONSIDERATIONS

The philosophy presiding over the design of the CLINICAL REFERENCE LIBRARY was to minimize the technical burden associated with the development, maintenance, and use of the computerized medical information "modules".

The use of nonskilled users requires that the CLINICAL REFERENCE LIBRARY be menu-driven. Explicit instructions are available, at every step in the CLINICAL REFERENCE LIBRARY. This, combined with user-oriented displays, provides the user with the information needed to pinpoint his/her position in the CLINICAL REFERENCE LIBRARY at all times. The ability to exit a module from any level at any time and to access any module are also important in this respect.

All the information in the CLINICAL REFERENCE LIBRARY file is stored on magnetic tape and is available 24 hours a day. The response time of the user-computer interactions is very rapid. The system is self-instructing.

Because of the highly illustrative nature of much of what is presented in traditional medical and allied health education, graphics are a necessary component of the CLINICAL REFERENCE LIBRARY. Unfortunately, only one graphics terminal (model HP 2648A) has been installed in the University Hospital ICU. All graphics are therefore presented to the user on paper. A 107-page binder containing 75

laminated illustrations and 11 tables designed by the author are immediately adjacent to all computer terminals.

DEVELOPMENT OF INFORMATION MODULES

The content of the clinical information modules was based on consideration of common and potentially serious medical problems frequently encountered in the intensive care unit. The charts of 75 patients admitted to the University Hospital ICU during the first 2 months of 1981 were reviewed. Twenty disease processes or clinical problems were chosen and developed for the CLINICAL REFERENCE LIBRARY from this chart review (Table 1).

Each module consists of many computer displays (ranging from 5 to 186) and contains information needed for optimal patient care. Where applicable, information basic for any single problem was classified under the following headings:

1) definition
2) incidence
3) etiology
4) bacteriology/pathology/pathophysiology
5) clinical course
6) diagnosis
7) treatment
8) complications
9) prognosis
10) references

Table 1

Content of the CLINICAL REFERENCE LIBRARY

1. The problem oriented medical record
2. Airway management including intubation and tracheostomy
3. Pulmonary physiology
4. Acid-base regulation
5. Gas transport
6. The pathophysiology of acid-base abnormalities
7. Pulmonary embolism
8. Aspiration pneumonia
9. Septic shock
10. Adult Respiratory Distress Syndrome (ARDS)
11. Pediatric medications including dosages, intervals and routes of administration
12. Drug interactions including adverse effects and possible mechanisms
13. Acute poisonings (acetaminophen, barbiturates, acid alcohols, carbon monoxide, salicylates and tricyclic antidepressants)
14. Antimicrobial therapy
15. The pathophysiology of starvation and the principles of hyperalimentation
16. Brain resuscitation and ICP monitoring
17. Flow-directed balloon-tipped catheter monitoring
18. Hypothermia
19. Burns
20. The pathophysiology, diagnosis and management of cardiac arrhythmias

The "common format" is based on McWhinney's analysis of common problem-solving errors (45):

1) the failure to respond to cues presented by the patient due to physician inexperience or due to the mental set of the physician
2) premature convergence on a diagnostic hypothesis and failure to consider alternate hypotheses
3) errors in diagnostic strategy (i.e. redundancy and inadequacy of testing), and
4) management errors.

It is apparent from this list that failure to remain well informed can be related directly to these problem-solving errors. Conversely, these errors are related to the specific components of the "common format" data base.

The modules were developed during the latter 6 months of 1981 and, except for occasional revisions based on user suggestions (e.g. spelling and punctuation) and updating of the references, remained stable during the period of the study. Creation and updating of the modules were the responsibility of the author. Information from recent textbooks and journal articles was converted into workable computer displays with appropriate reference citations. An audit of the medical content was completed before the modules were incorporated into the CLINICAL REFERENCE LIBRARY. Recognized and respected authorities in various medical and surgical specialties were invited to criticize the content of the modules for accuracy, currency and completeness. The author reviewed their suggestions and criticisms. Appropriate changes were made where necessary. Opposing views and opinions were expressed

in areas of controversy (i.e. the best possible therapy, recommended practices, etc.).

Revision of the text can be easily acommplished with the use of a visual editor. This does not require disruption of the CLINICAL REFERENCE LIBRARY. Changes in the programming of the prompts, etc. can be easily performed using preconstructed utility programs.

SYSTEM OPERATION

The author assumes that the user is totally naive about computers. Consequently, equipment is limited to three familar PDMS elements:

1) a television monitor
2) a hand-held keyboard reminiscent of the touch-tone telephone, and
3) a typewriter keyboard (of which only 14 keys are necessary for operation of the CLINICAL REFERENCE LIBRARY).

The level of understanding need be no greater than the ability to read and follow directions. Operation of the CLINICAL REFERENCE LIBRARY requires only six simple commands (APPENDIX 1).

When a resident decides that the clinical management of a critically ill patient is likely to be difficult or that he/she lacks sufficient knowledge about a particular clinical problem, he/she can consult the CLINICAL REFERENCE LIBRARY. After entering his/her personal identification number the user is immediately presented with an index or "main menu" of twenty problems or problem areas ("modules") (APPENDIX 2). Having typed a module number, for example 17, he/she is presented with an index to "ACUTE POISONINGS" (APPENDIX 3). The user then has several options:

1) he/she can start at the beginning of the module and continue through the module as if he/she were reading a book, or
2) he/she can directly access a specific heading or subheading e.g. 17.1.5 TREATMENT (OF ACETAMINOPHEN POISONING) and continue through that section as if he/she were reading a chapter in a book, or
3) he/she can directly access a specific page within the module and continue on from there e.g. on page 9, entitled 17.1.3 PATHOLOGY AND PATHOPHYSIOLOGY (OF ACETAMINOPHEN POISONING), the major pathophysiological aspects are presented.

After using the CLINICAL REFERENCE LIBRARY, the user can immediately sign-off or, more preferably, can access a nine-part questionaire (APPENDIX 4).

SUMMARY

This chapter was devoted to the description of the CLINICAL REFERENCE LIBRARY. The conceptual framework and philosophy, engineering considerations and development of the clinical information modules were described. Operation of the CLINICAL REFERENCE LIBRARY was also presented. The next chapter describes the methodology employed to evaluate the effectiveness of the CLINICAL REFERENCE LIBRARY as a teaching tool.

CHAPTER VI

MATERIALS AND METHODS

In this chapter the methodology employed to evaluate the effectiveness of the CLINICAL REFERENCE LIBRARY as a teaching tool is described. The chapter is divided into five parts. Part one describes the experimental design. Part two describes the participants. Qualitative and quantitative data gathering techniques are described in part three. Part four documents how the results of the pre- and post-test examinations and questionaires are combined in the final analysis. The chapter is summarized in part five.

DESCRIPTION OF PARTICIPANTS

Sixty-nine health care personnel were evaluated prospectively over a 12-month period. Forty-six participants were assigned to the control group which was composed of 8 medical students, 9 nurses and 10 residents from the Royal Alexandra Hospital ICU and 8 medical students, 4 nurses and 7 residents from the University Hospital ICU. Twenty-three health care personnel were assigned to the experimental group which was composed of 8 medical students, 8 nurses and 7 residents from the University Hospital ICU.

Three or four second- or third year residents were assigned to each ICU for 2- or 3-month overlapping rotations. The resident population was composed of trainees in Internal Medicine, General Surgery, Orthopedic Surgery and Anesthesia. Prior experience in critical care medicine or allied fields was variable. Most residents had had experience in at least one of the following: coronary care, neonatology, post-operative cardiac recovery, anesthesia or adult critical care.

One or two third or fourth year medical students were assigned to either ICU for four weeks at a time. Prior experience in critical care

medicine was negligible in this subgroup.

Only nurses permenantly working in the intensive care unit were involved in this study. Nurses not trained in critical care were not eligible. All the nurses had similar backgrounds and work experience.

EXPERIMENTAL DESIGN

The study was a classical, non-randomized, pre-test-post-test, control-experiment research paradigm. This design is one in which a group which has experienced "X" (in this case, the CLINICAL REFERENCE LIBRARY) is compared with one which has not, for the purpose of establishing the effect of "X" (11). This is graphically illustrated as:

O X O

O O

In the interest of the time, the study was divided into two phases. During the first phase, all participants entering the study were assigned to the control group (August 16, 1981 - February 14, 1982). This part of the study was conducted during the development of the CLINICAL REFERENCE LIBRARY and was terminated as soon as it became operational. During the second phase (February 15, 1982 - August 15, 1982), all participants entering the study were assigned to the experimental group and were allowed unlimited access to the CLINICAL REFERENCE LIBRARY. Participants were not randomly assigned to either ICU or either control or experimental group. Resident and medical student assignment was determined by the Director of Resident Training and the Phase III Co-ordinator, respectively. Neither official was affiliated with the study.

All participants were pre- and post-tested using the same multiple

choice question examination. Medical students and residents were tested no later than 72 hours after commencing their ICU rotation and no later than 24 hours after leaving the service. The average interval between pre- and post-testing was 4 weeks and 10 weeks for medical students and residents, respectively. The third subgroup, the nurses, was somewhat different in that at the time of testing many had already been working in the ICU for several years. Because the nurses also worked shift work, they were pre- and post-tested at their convenience. The average interval between tests for the nurses was 12 weeks.

During the course of the study both groups were encouraged to use conventional methods of learning e.g. textbooks, journals, bedside rounds, and consultation with staffmen and fellow colleagues. Thus, the only substantial difference between the two study groups involved exposure to the CLINICAL REFERENCE LIBRARY.

INSTRUMENTS

The Multiple Choice Question Examination

A comprehensive multiple choice question examination was designed to examine knowledge in the field of critical care medicine and to measure the acquisition of such knowledge after working in the ICU for a predetermined time. The questions were designed to not only discriminate between the major groups of participants but also between the various subgroups (e.g. medical residents versus surgery residents and senior nurses versus nurses with minimal experience).

The examination covered pulmonary physiology, emergency resuscitation, infection and bacteriology, homeostasis, shock, respiratory care and pulmonary complications, nutrition, and common pharmacologic agents

used in respiratory care and anesthesia. The examination was designed by the author and reviewed by a panel of three critical care specialists.

The examination was divided into two sections. Part I consisted of 99 "type A" questions (only one possible answer) and Part II consisted of 51 "type K" questions (four alternative answers in one of five possible combinations).

Each of the examinees were asked to answer seven demographic questions (Questions 151 - 157) concerning professional qualifications, postgraduate education and background and the relevancy of the content of the examination to the discipline of critical care medicine (APPENDIX 4).

The instructions for the technique in marking the answer sheet were presented at the beginning of each section and were reviewed with the examinees by an invigilator at the time of the examination. The time limit was exactly two hours. The answer sheets were scored by optical scanner.

Logging of User Performance

The following data were automatically recorded for each user - CLINICAL REFERENCE LIBRARY encounter:

1) the date, start time and total elapsed time of the encounter
2) the personal identification number of the user, and
3) the modules accessed and the total elapsed time on each module.

Questionaires

The following data were recorded if the user elected to respond to

the prompts of a questionaire (APPENDIX 5):

1) the purpose of the encounter i.e. problem-solving, continuing medical education or recreation
2) if the CLINICAL REFERENCE LIBRARY was accessed for problem-solving, was the information present and, if so, was it helpful?
3) the performance of the CLINICAL REFERENCE LIBRARY with respect to the library, staffmen, fellow colleagues and attending seminars
4) a rating of the medical content of the CLINICAL REFERENCE LIBRARY
5) a rating of user competence before and after accessing the CLINICAL REFERENCE LIBRARY
6) the degree to which the user feels the CLINICAL REFERENCE LIBRARY added to his/her fund of knowledge, and
7) overall evaluation of the CLINICAL REFERENCE LIBRARY and its comparison to other teaching methods.

Each participant answered a questionaire similar to that described above after writing the post-test examination (APPENDIX 6).

ANALYSIS OF DATA

An analysis of variance was used to test the differences of participant mean performance on the basis of a multiple choice question examination. The alpha level was set at 0.05. This procedure was used to determine intergroup differences for the pre- and post-tests (i.e. medical students versus nurses versus residents). Using gain scores as data inputs the independent samples t-test was used to determine

differences between comparable populations in the experimental and control groups (i.e. residents versus residents, nurses versus nurses and medical students versus medical students) for the pre- and post-tests.

The questionaire data were summarized by user group as follows:

1) the modules accessed
2) the reason for accessing the CLINICAL REFERENCE LIBRARY
3) the overall rating of the CLINICAL REFERENCE LIBRARY
4) the rating of the medical content of the CLINICAL REFERENCE LIBRARY
5) the rating of user competence before and after using the CLINICAL REFERENCE LIBRARY
6) the degree to which the user felt the CLINICAL REFERENCE LIBRARY added to his/her fund of knowledge, and
7) the overall evaluation of the CLINICAL REFERENCE LIBRARY with respect to other teaching methods.

The following logging data were cross tabulated by user group:

1) the modules accessed and the total duration of time spent on each module, and
2) the number of accesses to the CLINICAL REFERENCE LIBRARY.

SUMMARY

In this chapter, the methodology employed to evaluate the effectiveness of the CLINICAL REFERENCE LIBRARY as a teaching tool was described. The experimental design and the qualitative and quantitative data gathering techniques were also described. The chapter also documents how the results were combined in the final analysis. The results are

presented in the next chapter.

CHAPTER VII

RESULTS

This chapter presents the results of the quantitative and qualitative techniques used to evaluate the CLINICAL REFERENCE LIBRARY. The chapter is divided into four parts. The first part is devoted to the analysis of the multiple choice question examination which was used to determine cognitive gain. The results of the computer log are presented in part two. The results of the questionaires are presented in part three. The chapter is summarized in part four.

INTRODUCTION

Eighty-six subjects participated in this study. Participants had similar backgrounds (i.e. training, experience) in their respective subgroups. All participants assigned to the control group (16 medical students, 13 nurses, and 17 residents) completed the pre- and post-test examinations. Of the 40 participants assigned to the experimental group, only 23 ultimately finished. Twelve (60%) of the nurses and 5 (42%) of the residents withdrew from the study. Reasons for not continuing included:

1) too busy to take part (eleven nurses and five residents), and
2) termination of employment (one nurse).

All medical students assigned to the experimental group completed the pre- and post-test examinations. Sixty-nine participants were evaluated prospectively over a 12-month period.

EXAMINATION RESULTS

Tables 2 and 3 present the descriptive statistics for the control and experimental groups. The results are graphically illustrated in Figure 1. Tests for the homogeneity of variances across groups revealed

no statistically significant difference between comparable subgroups (i.e. medical students versus medical students, nurses versus nurses, and residents versus residents).

Table 2

Results of the Multiple Choice Question Examinations I

CONTROL GROUP

	N	PRE-TEST $\bar{X}$	PRE-TEST S	POST-TEST $\bar{X}$	POST-TEST S	MEAN DIFFERENCE	SIGNIFICANCE LEVEL
Medical Students	16	63.5	12.1	75.2	11.2	+11.7	$p<0.05$
Nurses	13	47.9	10.5	51.9	12.2	4.0	NS
Residents	17	76.1	13.4	88.1	13.9	+12.0	$p<0.05$

EXPERIMENTAL GROUP

	N	PRE-TEST $\bar{X}$	PRE-TEST S	POST-TEST $\bar{X}$	POST-TEST S	MEAN DIFFERENCE	SIGNIFICANCE LEVEL
Medical Students	8	60.8	13.1	91.5	13.1	+30.7	$p<0.05$
Nurses	8	47.1	9.4	48.6	9.3	+1.5	NS
Residents	7	72.3	10.7	102.9	16.8	+30.6	$p<0.05$

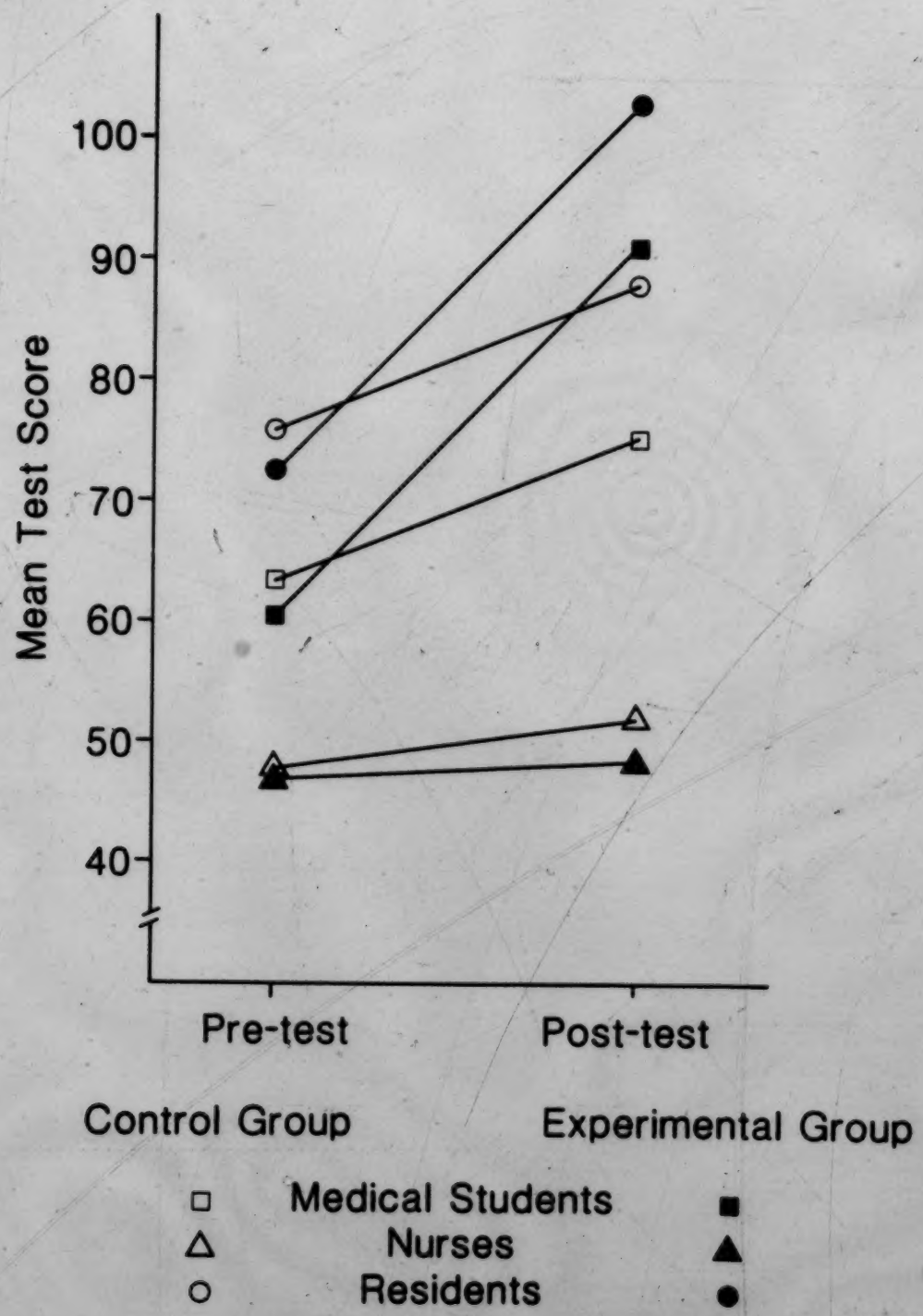

Figure 1: Participant Performance on the Multiple Choice Question Examinations

With regard to the control group, medical students had mean scores of 63.5 and 75.2 (out of a possible 150) on the pre- and post-tests, respectively ($t=-7.78$, $df=15$, $p<0.05$). The residents' mean score on the pre-test was 76.1 and rose to 88.1 on the post-test ($t=-7.68$, $df=16$, $p<0.05$). Nurses had pre- and post-test mean scores of 47.9 and 51.9, respectively ($t=-1.65$, $df=12$, $p>0.05$). Medical students and residents increased their mean test scores on the average of about 12 questions while the nurses increased their mean test scores by only 4 questions. These results are summarized in Table 2.

With regard to the experimental group, the mean score for the medical students on the pre-test was 60.8 and rose to 91.5 on the post-test ($t=-14.0$, $df=7$, $p<0.05$). Residents had a mean score of 72.3 and 102.9 on the pre- and post-tests, respectively ($t=-6.17$, $df=6$, $p<0.05$). Nurses had pre- and post-test mean scores of 47.1 and 48.6, respectively ($t=-1.97$, $df=7$, $p>0.05$). Medical students and residents increased their mean test scores by about 31 questions while the nurses increased their mean test scores by about 2 questions. These results are summarized in Table 2.

The pre-test mean scores between participants in each subgroup revealed no statistically significant difference between the control and experimental groups. However, the difference in post-test mean scores between experimental and control medical students was statistically significant ($p<0.05$). This was also true for the difference in posttest mean scores between experimental and control residents. There was, however, no significant cognitive "gain" in the nurse subgroups ($p>0.05$). These results are summarized in Table 3.

Table 3

Results of the Multiple Choice Question Examinations II

PRE-TEST

	CONTROL $\bar{X}$	EXPERIMENTAL $\bar{X}$	MEAN DIFFERENCE	SIGNIFICANCE LEVEL
Medical Students	63.5	60.8	-2.7	NS
Nurses	47.9	47.1	-0.8	NS
Residents	76.1	72.3	-3.8	NS

POST-TEST

	CONTROL $\bar{X}$	EXPERIMENTAL $\bar{X}$	MEAN DIFFERENCE	SIGNIFICANCE LEVEL
Medical Students	75.2	91.5	+16.3	$p<0.05$
Nurses	51.9	48.6	-3.3	NS
Residents	88.1	102.9	+14.8	$p<0.05$

LOGGING RESULTS

Analyses of the logging data are presented in Tables 4 and 5. The CLINICAL REFERENCE LIBRARY was accessed 496 times. A total of 576 modules were accessed. During the period of the study, (February 15 to August 14, 1982) the CLINICAL REFERENCE LIBRARY was utilized for a total of 141.7 hours.

Table 4

CLINICAL REFERENCE LIBRARY Logging Data I

MODULE	NUMBER OF ACCESSES				TIME ELAPSED (MIN)			
	Medical Students	Nurses	Residents	Total	Medical Students	Nurses	Residents	Total
1	8	7	7	22	65	46	25	136
2	10	14	15	39	312	162	206	680
3	23	18	15	56	651	113	215	979
5	27	11	11	49	673	130	203	1006
6	13	1	6	20	415	22	121	558
7	13	3	4	20	254	9	150	413
10	9	3	14	26	128	19	178	325
11	10	2	13	25	187	13	73	273
12	6	7	8	21	180	51	64	295
13	11	2	5	18	121	16	36	173
14	5	7	18	30	56	34	31	121
15	7	7	6	20	7	24	14	45
17	15	8	47	70	505	54	352	911
18	10	5	24	39	189	83	186	458
19	13	-	7	20	279	-	195	474
20	7	4	11	22	256	60	50	366
23	15	7	18	40	422	55	338	815
24	3	-	7	10	15	-	19	34
25	9	1	-	10	99	19	-	118
26	4	5	10	19	198	30	15	324

Table 5

CLINICAL REFERENCE LIBRARY Logging Data II

	NUMBER OF MODULES ACCESSED	TOTAL TIME ELPASPED (MIN)	(HR)	AVERAGE ACCESS TIME (MIN)
Medical Students	218	5012	83.5	23.0
Nurses	112	940	42.5	8.4
Residents	246	2552	15.7	10.4

Although the medical students accessed the system less often than the residents (218 versus 246 accesses) they spent more time utilizing the system (average access time about 23 minutes versus 10.4 minutes). The six most frequently accessed modules were ACID-BASE REGULATIION, PULMONARY PHYSIOLOGY, ACUTE POISONINGS, INVASIVE HEMODYNAMIC MONITORING, OXYGEN AND CARBON DIOXIDE TRANSPORT and ENDOTRACHEAL INTUBATION AND TRACHEOSTOMY. Almost 47% of the medical students' time were spent on the basic science programs (modules #1,2,3,5,6, and 7) (APPENDIX 2). The total time spent on the CLINICAL REFERENCE LIBRARY by the medical students was about 83.5 hours.

Analysis of the nurse logging data was disappointing. The nurses accessed the CLINICAL REFERENCE LIBRARY less than one half the number of times of either the residents or the medical students. Fifty percent of the nurses accessed four or less modules. The three most frequently used modules were ENDOTRACHEAL INTUBATION, PULMONARY PHYSIOLOGY and ACID-BASE REGULATION. Average access time was about 8.4 minutes. The total time spent on the CLINICAL REFERENCE LIBRARY by the nurses was about 15.7 hours.

The two most utilized modules by the residents were ACUTE POISONINGS

AND INVASIVE HEMODYNAMIC MONITORING. One resident spent more than 50% of his/her time on ACUTE POISONINGS. Four of the seven residents accessed more than 1/4 of the modules. The average access time was about 10.4 minutes. The total time spent on the CLINICAL REFERENCE LIBRARY was 42.5 hours.

RESULTS OF QUESTIONAIRES

The computer questionaire (APPENDIX 5) was answered on 97 different occasions. The CLINICAL REFERENCE LIBRARY was accessed 496 times. Despite this poor response, it was possible to deduce the following generalizations:

1) medical students and nurses used the CLINICAL REFERENCE LIBRARY for continuing medical education
2) residents used the CLINICAL REFERENCE LIBRARY primarily for problem-solving, and
3) medical students spent longer periods of time at the terminal than either the residents or nurses.

The remainder of this section is devoted to the analysis of the questionaire administered after the post-test examination (APPENDIX 6). User responses to this questionaire are presented in Tables 6 to 11.

In general, those participants who completed the sequence of modules found the experience rewarding. The most negative responses or the lack of positive responses were expressed by the nurses.

Use of the CLINICAL REFERENCE LIBRARY

QUESTION 1 confirmed that medical students and nurses used the CLINICAL REFERENCE LIBRARY for continuing medication while residents

most often used the system for problem-solving. The results are presented in Table 6.

Table 6

QUESTION 1: Which of the following was the most common reason for accessing the CLINICAL REFERENCE LIBRARY?

	Problem-Solving	Continuing Medical Education	Recreation
Medical Students	-	8/8	-
Nurses	-	8/8	-
Residents	6/7	1/7	-

User Assessment of the CLINICAL REFERENCE LIBRARY

QUESTIONS 2 to 8 were designed in such a way that respondents were compelled to express a degree of agreement or disagreement on the subject in question.

All respondents rated the CLINICAL REFERENCE LIBRARY as average or above average with respect to the hospital library, consultation with staffmen or fellow colleagues or attending seminars (QUESTION 2). Nurses were more likely to be indifferent whereas residents or medical students felt that the CLINICAL REFERENCE LIBRARY was more useful than the library, consultation with fellow colleagues or by attending seminars. The results are presented in Table 7.

Table 7

QUESTION 2: How would you rate the CLINICAL REFERENCE LIBRARY...

a. compared to the library?

	useless 1	2	3	4	5 useful
Medical Students	-	-	-	3/8	5/8
Nurses	-	-	6/8	-	2/8
Residents	-	-	-	-	7/7

b. compared to consultation with staffmen?

	useless 1	2	3	4	5 useful
Medical Students	-	-	5/8	-	3/8
Nurses	-	-	-	1/8	7/8
Residents	-	-	-	4/7	3/7

c. compared to consultation with fellow colleagues?

	useless 1	2	3	4	5 useful
Medical Students	-	-	-	-	8/8
Nurses	-	-	5/8	1/8	2/8
Residents	-	-	-	-	7/7

d. compared to attending seminars?

	useless 1	2	3	4	5 useful
Medical Students	-	-	-	-	8/8
Nurses	-	-	5/8	1/8	2/8
Residents	-	-	-	-	7/7

Users were asked in QUESTION 3 to rate the medical content of the CLINICAL REFERENCE LIBRARY. All medical students and residents felt that the information was very valuable, current, accurate and medically precise. The nurses were more negative about the value of the CLINICAL

REFERENCE LIBRARY. The results are presented in Table 8.

Table 8

QUESTION 3: How would you rate the medical content of the CLINICAL REFERENCE LIBRARY?

a. worthless	1	2	3	4	5	valuable
Medical Students	-	-	-	-	8/8	
Nurses	-	-	1/8	2/8	5/8	
Residents	-	-	-	-	7/7	
b. out-of-date	1	2	3	4	5	current
Medical Students	-	-	-	-	8/8	
Nurses	-	-	-	-	8/8	
Residents	-	-	-	-	7/7	
c. contains errors	1	2	3	4	5	error-free
Medical Students	-	-	-	-	8/8	
Nurses	-	-	-	-	8/8	
Residents	-	-	-	-	7/7	
d. medically imprecise	1	2	3	4	5	medically precise
Medical Students	-	-	-	-	8/8	
Nurses	-	-	-	-	8/8	
Residents	-	-	-	-	7/7	

Most respondents, especially medical students and residents, felt that they acquired knowledge during their rotation through the intensive care unit and that such knowledge was attributable to the CLINICAL REFERENCE LIBRARY (QUESTIONS 4 to 6). Two nurses felt that the CLINICAL REFERENCE LIBRARY contributed significantly to their knowledge. The other nurses were not otherwise impressed. The results are presented in Table 9.

Table 9

QUESTION 4: How would you rate your level of overall competence in critical care medicine before using the CLINICAL REFERENCE LIBRARY?

	average or below average	1	2	3	4	5	outstanding
Medical Students		5/8	3/8	-	-	-	
Nurses		5/8	3/8	-	-	-	
Residents		1/7	3/7	3/7	-	-	

QUESTION 5: How would you rate your level of overal compentence in critical care medicine after using the CLINICAL REFERENCE LIBRARY?

	average or below average	1	2	3	4	5	outstanding
Medical Students		-	-	5/8	3/8	-	
Nurses		5/8	1/8	2/8	-	-	
Residents		-	-	1/7	6/7	-	

QUESTION 6: To what degree do you feel that the CLINICAL REFERENCE LIBRARY added to your fund of knowledge during your rotation through ICU?

	did not add	1	2	3	4	5	did add
Medical Students		-	-	-	5/8	3/8	
Nurses		5/8	1/8	1/8	1/8	-	
Residents		-	-	-	6/7	1/7	

Most participants felt that the effort invested in using the CLINICAL REFERENCE LIBRARY was worthwhile (QUESTION 7). About 75% of the nurses were noncommital. The results are presented in Table 10.

Table 10

QUESTION 7: Learning this material by computer was...

	a. a waste of time	1	2	3	4	5	time well spend
Medical Students		-	-	-	1/8	7/8	
Nurses		1/8	-	5/8	2/8	-	
Residents		-	-	1/7	5/7	1/7	
	b. boring	1	2	3	4	5	enjoyable
Medical Students		-	-	-	6/8	2/8	
Nurses		-	-	6/8	1/8	1/8	
Residents		-	-	1/7	5/7	1/7	
	c. unsatisfying	1	2	3	4	5	satisfying
Medical Students		-	-	-	4/8	4/8	
Nurses		-	-	6/8	1/8	1/8	
Residents		-	-	-	6/7	1/7	

QUESTION 8 was designed to determine which teaching methods the participants preferred. Nurses preferred consultation with staffmen or one of their peers and bedside teaching. Only 50% of the nurses preferred computer-presented material. Medical students and residents unanimously preferred seminars, bedside teaching, computer-presented material and discussion with staffmen. The results are presented in Table 11.

Table 11

QUESTION 8: Which of the following teaching methods do you prefer?

	Computer-Presented Material	Seminars	Reading		Discussion with		Beside Teaching
			Textbooks	Journals	Staffmen	Colleagues	
Medical Students	8/8	8/8	1/8	-	8/8	4/8	8/8
Nurses	4/8	5/8	-	-	7/8	6/8	8/8
Residents	7/7	7/7	4/7	5/7	7/7	6/7	7/7

SUMMARY

In this chapter, the results of the evaluative process of the CLINICAL REFERENCE LIBRARY were presented. Three specific findings emerged from the data:

1) medical students and residents exposed to the CLINICAL REFERENCE LIBRARY "acquired" more knowledge than their control counterparts using conventional teaching methods
2) medical students and nurses accessed the CLINICAL REFERENCE LIBRARY for continuing medical education whereas residents used the system primarily for problem-solving, and
3) a general attitudinal ambivalence was directed toward the CLINICAL REFERENCE LIBRARY by the nurses.

The next chapter is devoted to discussion of the results and recommendations for further research and development.

CHAPTER VIII

DISCUSSION AND RECOMMENDATIONS FOR FURTHER RESEARCH AND DEVELOPMENT

There have been no reports on the effect of computer-presented information on medical knowledge acquisition in the intensive care unit. Indeed, the degree of cognitive gain in any clinical environment involving a computer-based information system has not been previously documented. Under laboratory conditions, however, computer-based education has contributed to the acquisition of knowledge (46).

In this study medical students and residents demonstrated significant gains in knowledge during their rotation through the intensive care unit. This result was not unexpected in that these individuals are training to be physicians, albeit they are at different levels of training. One would also expect medical students to be less knowledgeable than residents. This was confirmed in both the control and experimental groups by analysis of the pre- and post-test mean scores. Most importantly, however, medical students and residents exposed to the CLINICAL REFERENCE LIBRARY demonstrated statistically significant gains in knowledge when compared to their control counterparts.

These results do not mean that the gains in knowledge by these two groups was due to the CLINICAL REFERENCE LIBRARY per se. Ideally, one would hope that the CLINICAL REFERENCE LIBRARY was the source for their knowledge. It is possible, however, that other factors account for this gain:

1) the information contained within the CLINICAL REFERENCE LIBRARY stimulated further interest, thereby compelling the user to seek more knowledge elsewhere
2) the CLINICAL REFERENCE LIBRARY reinforced or supplemented

knowledge acquired elsehwere or by other means, or

3) the information contained within the CLINICAL REFERENCE LIBRARY was insufficient, thereby requiring the user to look elsewhere .

The role of the CLINICAL REFERENCE LIBRARY as a teaching tool was confirmed in part by the reasons why the CLINICAL REFERENCE LIBRARY was used by the various participants. Medical students and nurses used the CLINICAL REFERENCE LIBRARY for continuing medical education. The preference of medical students to access basic science material for long periods supports this. On the other hand, residents cited problem-solving as the most common reason for using the CLINICAL REFERENCE LIBRARY. Residents tended to access clinical topics more often and for shorter periods of time; that is, they were probably looking for information.

On at least two separate occasions, a resident was known to access the CLINICAL REFERENCE LIBRARY for the purpose of gathering information for ICU service rounds. The sections reviewed were methanol poisoning and ethylene glycol poisoning.

A secondary but equally important role was the use of the CLINICAL REFERENCE LIBRARY as a "check" on patient management. Again, the most popular module was ACUTE POISONINGS. The clinical problems most likely to require "checking" were acid alcohol poisoning and overdose due to tricyclic antidepressants.

It is interesting to note that the most frequently utilized modules, ACUTE POISONINGS, PULMONARY PHYSIOLOGY, ENDOTRACHEAL INTUBATION AND TRACHEOSTOMY, ACID-BASE REGULATION and INVASIVE HEMODYNAMIC MONITORING, are topics intimately associated with the management of the critically ill patient. Although many of the topics in the CLINICAL REFERENCE

LIBRARY pertain to the practice of medicine in general, ACUTE POISONINGS and INVASIVE HEMODYNAMIC MONITORING are topics confined primarily to the area of critical care medicine. As a group, the residents accessed these two topics most often. Medical students, on the other hand, preferred ACID-BASE REGULATION and PULMONARY PHYSIOLOGY. ENDOTRACHEAL INTUBATION and TRACHEOSTOMY and PULMONARY PHYSIOLOGY were the two most popular topics with the nurses.

The participation of the nurses assigned to the experimental group was disappointing. However, this ambivalence was not unexpected despite the author's attempts to encourage participation. There are at least three possible explanations as to why the nurses did not demonstrate significant gains in knowledge after using the CLINICAL REFERENCE LIBRARY. First, there is at this time a general ambivalence among nurses, a factor which is beyond the control of the author. The nursing profession is plagued with labor unrest and manpower problems.

The second explanation is based on the nurses' attitudes toward the Patient Data Management System. Even though the PDMS was introduced to the intensive care unit in November of 1980, there still remain strong negative views directed toward the use and the feasibility of computerized patient data management. Nurses have expressed the following views about the PDMS (and not the CLINICAL REFERENCE LIBRARY) to the author on numerous occasions:

1) the PDMS takes time away from patient
2) the PDMS has been plagued with numerous "bugs" and "down times"
3) data is often duplicated by hand before the ultimate hard copy is produced
4) some nurses lack basic typing skills, and

5) the mechanics of the system are difficult to learn.

Nurses tend to resist the introduction of alteration of any routine. This was most noticeable a few years ago with the introduction of hemodynamic monitoring in our unit. It can be argued that a negative attitude directed toward the PDMS can also be referred to the CLINICAL REFERENCE LIBRARY merely because of its intimate association with the PDMS.

Thirdly, the lack of sufficient encouragement by the senior nursing staff, in the author's opinion, was instrumental in the failure to acquire sufficient data from this subgroup. The Charge Nurse and two Assistant Charge Nurses were eager to participate in the study and offered to act as a liaison between the author and the other nurses. All three withdrew from the study shortly after it was started.

On the basis of these findings, the following suggestions for further research are presented. The CLINICAL REFERENCE LIBRARY, like the problem oriented medical record, must become an integral part of the intensive care delivery system before further attempts are made to evaluate its role and effectiveness in critical care medicine. A well-structured unit with a stable multidisciplinary team with a true commitment to the care of the critically ill is required. The Director(s), Charge Nurse and Chief Resident must also have a genuine belief in the concept of the CLINICAL REFERENCE LIBRARY. The responsibility for the implementation of this proposal must lie with the Director. Then, and only then, can a more representative analysis of the CLINICAL REFERENCE LIBRARY in the ICU be made.

Underutilization and cost ineffectiveness are detrimental to the concept of the PDMS and the CLINICAL REFERENCE LIBRARY. Siegal

demonstrated a 20% increase in utilization of a computer-based physiologic CARE system by all personnel after the introduction of "living textbook" programs (59). The effect of the CLINICAL REFERENCE LIBRARY on the utilization of the PDMS could be determined in the following manner. The study would be undertaken in two phases. Phase one would involve monitoring the use of the PDMS. The following data would be automatically recorded for each user-computer encounter:

1) the date, start time and total elapsed time
2) the personal identification number of the user, and
3) the subsystem accessed and the total time elapsed on each subsystem.

In phase two the CLINICAL REFERENCE LIBRARY would be introduced. Analyses would be performed for each group of participants (i.e. medical students, nurses and other paramedical personnel and residents). The results would be tabulated and analyzed for differences in the use of each of the subsystems across groups before and after the introduction of the CLINICAL REFERENCE LIBRARY.

Having demonstrated that medical students and residents acquire knowledge after exposure to an ICU computer-based clinical information system, the next step in user evaluation should include testing for proper patient management. For the purpose of clarity, proper patient management encompasses the institution of appropriate investigations, the development of diagnoses and the implementation of appropriate therapy. Testing for proper patient management could be accomplished by repeating the study described herein and using one or more of the following test instruments:

1) more sophisticated multiple choice questions

2) clinical scenarios requiring generation and rank ordering of investigations, differential diagnoses, or treatments, and
3) sophisticated computerized clinical scenarios requiring natural language input mode and which would require the generation and rank ordering of investigations, differential diagnoses and treatments.

A fourth and more sophisticated test would involve reviewing patients' charts and comparing what was reportedly done and/or documented about a clinical problem with a set of explicit criteria previously established by a group of specialists in critical care medicine. The minimum criteria required for the management of twelve problem areas within critical care medicine would be defined by a panel of critical care specialists. Topics or problem areas would include pulmonary embolism, aspiration pneumonia, septic shock, ARDS, acid alcohol poisoning, tricyclic antidepressant poisoning, salicylate poisoning, barbiturate overdose, inhalation injury, hypothermia, cerebral edema and hyperalimentation. Baseline measurements of patient management for each group would involve scrutinizing patients' charts for the documentation and management of clinical problems and comparing these components of patient care with the criteria previously established. Patient management by the experimental group would be examined by reviewing the CLINICAL REFERENCE LIBRARY log, the computerized questionaire, and patients' charts. Objective testing for patient management by the control group would involve reviewing patients' charts for the documentation and management of clinical problems. On the basis of these reviews, patient management would be analyzed and classified as superior, adequate or indeterminant. For example, in order for the

management of a patient with acid alcohol poisoning to be classified as adequate the patient must receive the following therapy:

1) support of respiratory failure and shock
2) correction of the metabolic acidosis
3) immediate hemodialysis, and
4) administration of alcohol.

For such an episode to be classified as superior, the following aspects of patient management must be performed:

1) documentation of serum acid alcohol levels
2) documentation of the urinalysis for oxalate crystals
3) documentation of the fundoscopic examination
4) documentation of the serum calcium and correction hypocalcemia, and
5) administration of thiamine and pyridoxine supplements (if ethylene glycol poisoning).

Both groups would be required to document all aspects of patient care by using the problem oriented medical record. Data on patient management of the two groups would then be tabulated and analyzed to determine if a computerized clinical information system affects clinicians' abilities to provide patient management.

The CLINICAL REFERENCE LIBRARY should be expanded to include topics such as ventilators, the metabolic response to trauma, blood component therapy, wound healing, acute renal failure, dialysis, cardiac tamponade, fat embolism syndrome and the management of trauma.

Lastly, a literature review committee should be set up to regularly update the information and the references of the clinical information modules. The primary goal of this committee should be to provide all

users of the CLINICAL REFERENCE LIBRARY with current and relevant information and literature. This committee should be composed of respected medical authorities and should include at least one individual who has an intimate knowledge about the operation and philosophy of the CLINICAL REFERENCE LIBRARY. Selection criteria for the reference material should include:

1) state of the art review articles
2) case studies with substantial reviews of the literature about a specific problem
3) articles about instrumentation and/or methodology if relevant clinical applications are explicitly described
4) editorials which discuss and evaluate an article selected from elsewhere in the journal
5) articles which compare treatment modalities which have direct clinical application, and
6) articles which compare drug mechanisms, side effects, contraindications, dosage, and drug interaction.

SUMMARY

The effects of the CLINICAL REFERENCE LIBRARY in the intensive care unit were discussed. Recommendations for further research included:

1) integration of the CLINICAL REFERENCE LIBRARY into the organization of the intensive care delivery system
2) evaluation of the user's ability to properly manage patients
3) expansion of the content of the CLINICAL REFERENCE LIBRARY, and
4) the formation of a review committee to update the clinical information modules.

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APPENDIX 1

OPERATIONAL COMMANDS FOR THE

CLINICAL REFERENCE LIBRARY

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CLINICAL REFERENCE LIBRARY          PG  1/  1

  TO:                                PUSH:
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GO FORWARD ONE PAGE                    GO

GO BACK ONE PAGE                       -GO

SELECT A PARTICULAR MODULE,
HEADING, SUBHEADING
  OR PAGE                          MM.HH.SS GO
                    OR             MM...PP GO
                    ETC

START AT A PARTICULAR LOCATION
                                ;MM.HH.SS.PP.  GO

RETURN TO A PREVIOUS LOCATION,
TABLE OF CONTENTS OR EXIT          0 GO

VIEW INSTRUCTIONS                  ;  GO
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APPENDIX 2

"MAIN MENU" OF THE CLINICAL REFERENCE LIBRARY

CLINICAL REFERENCE LIBRARY PG 1/ 2

1. PROBLEM ORIENTED MEDICAL RECORD
2. ENDOTRACHEAL INTUBATION AND TRACHEOSTOMY
3. PULMONARY PHYSIOLOGY
4.
5. ACID-BASE REGULATION
6. OXYGEN AND CARBON DIOXIDE TRANSPORT
7. THE H^+ APPROACH TO ACID-BASE PROBLEMS
8.
9.
10. ACUTE PULMONARY EMBOLISM
11. ADULT RESPIRATORY DISTRESS SYNDROME
12. SEPTIC SHOCK
13. ASPIRATION PNEUMONIA
14. PEDIATRIC MEDICATIONS
15. ADVERSE DRUG INTERACTIONS
16.
17. POISONINGS
18. ANTIMICROBIALS IN THE ICU

SELECT MODULE, OR PUSH GO FOR MORE

CLINICAL REFERENCE LIBRARY PG 2/ 2

19. NUTRITIONAL SUPPORT IN THE CRITICALLY ILL
20. RESUSCITATION OF THE INJURED BRAIN
21.
22.
23. INVASIVE HEMODYNAMIC MONITORING
24. HYPOTHERMIA
25. BURNS
26. ARRHYTHMIAS

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3

MODULE 17: ACUTE POISONINGS (PAGES 1-24)

POISONINGS PG 1/186

ACUTE POISONINGS

17.1.0 ACETAMINOPHEN TOXICITY

17.2.0 BARBITURATE POISONING

17.3.0 CARBON MONOXIDE POISONING

17.4.0 ETHYLENE GLYCOL POISONING

17.5.0 METHANOL POISONING

17.6.0 ACUTE SALICYLATE POISONING

17.7.0 TRICYCLIC ANTIDEPRESSANT POISONING

PUSH GO FOR MORE, OR ;GO FOR INSTRUCTIONS

POISONINGS PG 2/186

17.1.0 ACETAMINOPHEN TOXICITY

17.1.1 INTRODUCTION

17.1.2 PHARMACOLOGY

17.1.3 PATHOLOGY AND PATHOPHYSIOLOGY

17.1.4 CLINICAL COURSE

17.1.5 TREATMENT

17.1.6 PROGNOSIS

17.1.7 REFERENCES

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 3/186

17.1.1 INTRODUCTION

-acetaminophen (TYLENOL), a metabolite of phenacetin, has become increasingly popular as a substitute for the salicylates

-although allegedly safer than aspirin, the British experience indicates that acute acetaminophen overdosage is much more toxic than the salicylates

-this compound does not produce the hemorrhagic, gastrointestinal or acid-base disturbances of aspirin, but has a more subtle form of toxicity (nonspecific initial complaints, lack of coma, delay in on the set of jaundice and a rapid fall in detectable plasma levels)

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 4/186

17.1.2 PHARMACOLOGY

-acetaminophen (N-acetyl-p-aminophenol) is rapidly and almost completely absorbed from the gastrointestinal tract

-peak plasma concentrations occur within 30-90 minutes

-acetaminophen is uniformly distributed throughout most body fluids

-binding of the drug to plasma proteins is variable (negligible at therapeutic levels but 15-40% binding at higher concentrations)

-the plasma half-life is 1-3 hours

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 5/186

17.1.2 PHARMACOLOGY

-the half-life of acetaminophen does not change in renal function, but the apparent elimination half-life is prolonged in the presence of liver dysfunction or overdosage (about 8 hours in patients with severe liver damage)

-although about 3% of acetaminophen is excreted unchanged in the urine, 80% is excreted in the urine after conjugation in the liver

-indeed, 25% of an administered dose is metabolized in the first pass through the liver

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 6/186

17.1.2 PHARMACOLOGY

-hepatic conjugation is primarily with glucuronic acid and, to a lesser extent, with sulfuric acid (the former predominating in adults and the latter in children) (Figure 17-1)

-a minor toxic metabolite, formed by the mixed function oxidase (P450) system in the liver, is conjugated with glutathione and subsequently excreted as the cysteine and/or mercapturic acid derivatives

-liver cells can be exposed to higher levels of the toxic metabolite if the mixed function oxidase (P450) enzymes are induced by chronic consumption of ethanol, barbiturates, etc

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 7/186

17.1.2 PHARMACOLOGY

-in addition, glutathione stores may be depleted by starvation, inborn errors of metabolism and disease

-although single plasma levels are not as reliable as the plasma half-life in estimating prognosis, single plasma levels can be useful (Figure 17-2)

-levels > 300 mg/L at 4 hours or 120 mg/L at 12 hours are uniformly associated with hepatic damage

-levels < 120 mg/L at 4 hours or 50 mg/L at 12 hours are uniformly associated with a lack of hepatotoxicity

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 8/186

17.1.2 PHARMACOLOGY

-in acetaminophen therapy, the following points are pertinent:

1. no dosage readjustment is necessary in the presence of renal dysfunction (urinary excretion is insignificant)
2. it may be appropriate to use a reduced dosage in the presence of liver dysfunction, bearing in mind that there is no clinical evidence that liver dysfunction has occured with full therapeutic doses
3. based on current data, no dosage adjustment is necessary in the management of pain in geriatric populations
4. alcohol, B-adrenergic blockers, anticoagulants and chlorpromazine may interact with acetaminophen

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 9/186

17.1.3 PATHOLOGY AND PATHOPHYSIOLOGY

-pathologic changes in the liver of patients with hepatoxicity are primarily necrotic and nature (most marked

-there is no information available regarding the long-term effects of acetaminophen damage to the liver in those patients who have showed damage following overdosage

-follow-up liver biopsies at three months have demonstrated increased fibrous tissue (not cirrhosis)

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 10/186

17.1.3 PATHOLOGY AND PATHOPHYSIOLOGY

-remarkable elevations of AST, ALT and LDH are noted in those patients with hepatotoxicity

-elevated bilirubin levels are inconsistant with respect to the degree of hepatic damage

-myocardial damage has been documented (subendocardial hemorrhage and myocardial necrosis)

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 11/186

17.1.4 CLINICAL COURSE

-after 24 hours, clinical improvement is obvious and the patient may insist on getting up to walk around or even demand to be discharged

-however, a rising titre of AST or ALT, the development of an abnormal PT or elevated serum bilirubin (particularly if accompanied by the insidious onset of right upper quadrant abdominal pain), signifies the onset of hepatotoxicity

-between 48-72 hours post-ingestion, some degree of hepatic necrosis has set in with acute hepatic failure becoming more obvious with time

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 12/186

17.1.4 CLINICAL COURSE

-patients ingesting toxic quantities of acetaminophen demonstrate four clinical phases

-between 2-24 hours after ingesting a toxic dose, the patient experiences anorexia, nausea, vomiting, diaphoresis and malaise (CNS depression and coma are not a feature)

-by 8-10 hours, they are lying quietly, complaining of abdominal discomfort

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 13/186

17.1.4 CLINICAL COURSE

-rarely, anuria may develop in association with hepatic failure (the BUN may be disproportionately low as the liver damage prevents the formation of some urea)

-renal failure may be due to volume depletion secondary to vomiting and diaphoresis and/or the antidiuretic effect of the drug itself

-death is primarily due to hepatic failure and is dependent upon the degree of hepatic necrosis

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 14/186

17.1.4 CLINICAL COURSE

-the most sensitive indicator to the onset of hepatoencephalopathy is the development of constructional dyspraxia

-in spite of this, patients very rarely go on to die; in fact, if the symptoms are mild, even with a history of substantial ingestion, there is an 86% chance that hepatotoxicity will not occur

-the last phase is the stage of recovery, which is usually apparent by day 7 or 8, even if the transaminases have reached enormous levels

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 15/186

17.1.5 TREATMENT

1. prevention of absorption
   -despite the rapid gastrointestinal absorption of acetaminophen, prevention of further absorption should be attempted up to 24 hours following ingestion

   -this should include induction of emesis or copious gastric lavage (depending on the patient's level of consciousness) and administration of a cathartic and activated charcoal

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 16/186

17.1.5 TREATMENT

2. specific antidotes
   -N-acetylcysteine acts as a glutathione substitute and directly combines with the toxic metabolite

   -it is the drug of choice and must be given within 12 hours of ingestion

   -the dose of MUCOMYST is 140 mg/kg as a 5% solution with COCA COLA, PEPSI or fruit juice, followed by 70 mg/kg every four hours (total of 18 doses)

   -PARVOLEX can be given intravenously in an initial dose of 150 mg/kg in 200 ml of D5W over 15 minutes, followed by 100 mg/kg in one liter of D5W over the next 16 hours

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINIGS PG 17/186

17.1.5 TREATMENT

1. specific antidotes (cont)
   -patients with toxic blood levels who are treated with a full course of MUCOMYST have an excellent change of having only minimal, if any, hepatoxicity

   -patients with toxic blood levels and clinical signs of toxicity, between 16-24 hours, will probably not benefit from MUCOMYST and therefore have a higher probability of developing transient elevations of hepatic enzymes

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 18/186

17.1.5 TREATMENT

2. specific antidotes (cont)
   -patients with toxic levels after 24 hours and stage 2 symptoms are in greater danger of developing hepatotoxicity and MUCOMYST therapy is definitely too late

   -the patient who has overdosed over a periods of time, ie. a dozen tablets every few hours over a 12-16 hour period, is probably at great risk to develop hepatotoxicity and should be treated immediately with MUCOMYST

   -once severe hepatic toxicity has occured, treatment is supportive, with the hope that hepatic function will return

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 3 (continued)

POISONINGS PG 19/186

17.1.5 TREATMENT

2. specific antidotes (cont)
-glutathione is capable of inactivating the toxic intermediate metabolite via preferential conjugation in vivo

-therapeutic administration of glutathione has been unsuccessful because glutathione is incapable of crossing cell membranes

-dimercaptural, D-penicillamine or L-methionine bind the toxic metabolite in a manner similar to glutathione

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 20/186

17.1.5 TREATMENT

2. specific antidotes (cont)
-oral methionine (PENDAMETH) given as 4 doses of 40 mg/kg each, four hours apart has been shown to be effective in reducing the frequency and severity of acetaminophen-induced liver damage

-however, it is capable of aggravating pre-existing liver disease and should therefore be given no later than 10 hours post-ingestion

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 21/186

17.1.5 TREATMENT

2. specific antidotes (cont)
   -in theory, parenterally administered cysteine and cysteamine can inactivate the toxic intermediate metabolite (intravenous cysteamine is not available in North America)

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 22/186

17.1.5 TREATMENT

3. other measures
   -neither hemodialysis nor forced diuresis appear effective; even though hemodialysis reduces the plasma half-life of acetaminophen, there is no evidence tthat it alters the course of illness

   -peritoneal dialysis and hemoperfusion are ineffective because the highly toxic intracellular metabolite cannot be removed

   -exchange transfusion, cross circulation with laboratory animals and liver transplantation have all been performed with varying degrees of success

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 23/186

17.1.6 PROGNOSIS

-20% of patients with liver damage will die

-a single ingestion of less than 2 grams in an adult is probably safe (as little as 6 grams has been reported to be lethal)

SELECT MODULE, OR PUSH GO FOR MORE

POISONINGS PG 24/186

17.1.7 REFERENCES

*Nogan, A.G. and Bremner, J.E. "Fatal acetaminophen overdosage in a young child". J. OF PEDIATRICS 92:832-833, 1978.

*Rumack, B.H. et al. "Acetaminophen Overdose" ARCH. INT. MED. 141:380-385, 1981.

*Rumack, B.H. "Tylenol (Acetaminophen)". PROFILES IN THERAPEUTICS 2:1-7, 1981.

SELECT MODULE, OR PUSH GO FOR MORE

APPENDIX 4

DEMOGRAPHIC QUESTIONAIRE FROM THE MULTIPLE CHOICE QUESTION EXAMINATION

151. HOW LONG HAVE YOU BEEN ACTIVELY INVOLVED IN CRITICAL CARE MEDICINE?

A. NEVER

B. LESS THAN 3 MONTHS

C. 3 TO 6 MONTHS

D. 7 TO 12 MONTHS

E. MORE THAN ONE YEAR

152. YOUR PRIMARY PROFESSION IS:

A. MEDICAL STUDENT (ANSWER QUESTION 157)

B. NURSE (ANSWER QUESTIONS 153 AND 157)

C. PHYSICIAN (ANSWER QUESTIONS 154 TO 157)

D. OTHER (ANSWER QUESTION 157)

153. YOUR LEVEL OF NURSING TRAINING IS:

A. CRITICAL CARE NURSE

B. BACHELOR OF SCIENCE (NURSING)

C. REGISTERED NURSE

154. YOUR PRIMARY MEDICAL SPECIALTY IS:

A. ANESTHESIA

B. INTERNAL MEDICINE

C. SURGERY

D. PEDIATRICS

E. OTHER

155. YOUR LEVEL OF POSTGRADUATE TRAINING IS:

A. RESIDENT I

B. RESIDENT II

C. RESIDENT III

D. RESIDENT IV

E. RESIDENT V

156 YOU HAVE PREVIOUSLY ROTATED THROUGH:

A. ANESTHESIA

B. CORONARY CARE UNIT

C. ADULT ICU

D. NICU

E. CARDIOVASCULAR RECOVERY ROOM

157. HOW MANY OF THE 150 QUESTIONS ON THIS EXAMINATION DO YOU THINK ARE PERTINENT TO THE FIELD OF CRITICAL CARE MEDICINE?

A. 1 TO 30

B. 31 TO 60

C. 61 TO 90

D. 91 TO 120

E. 121 TO 150

APPENDIX 5

COMPUTER QUESTIONAIRE

1. Why did you access this program?
   a. problem-solving ie. problem with management of a patient
   b. continuing medical education
   c. recreation

2. Assuming that you accessed this program for problem-solving reasons:
   a. did you find the information you were seeking?
   b. did the information help resolve a problem or problems?

3. How would you rate the CLINICAL REFERENCE LIBRARY?
   a. compared to the library
      useless 1 2 3 4 5 very useful
   b. compared to consultation with staffmen
      useless 1 2 3 4 5 very useful
   c. compared to consultation with fellow colleagues
      useless 1 2 3 4 5 very useful
   d. compared to attending seminars
      useless 1 2 3 4 5 very useful

4. How would you rate medical content of CLINICAL REFERENCE LIBRARY?

a.	Worthless	1 2 3 4 5	valuable
b.	out-of-date	1 2 3 4 5	current
c.	contains errors	1 2 3 4 5	error-free
d.	medically imprecise	1 2 3 4 5	medically precise

5. How would you rate your level of overall competence in critical care medicine before using the CLINICAL REFERENCE LIBRARY?

average or below average 1 2 3 4 5 outstanding

6. How would you rate your level of overall competence in critical care medicine after using the CLINICAL REFERENCE LIBRARY?

average or below average 1 2 3 4 5 outstanding

7. To what degree do you feel that the CLINICAL REFERENCE LIBRARY added to your fund of knowledge during your rotation through the ICU?

did not add 1 2 3 4 5 did add

8. Learning this material by computer was:

a.	a waste of time	1 2 3 4 5	time well spent
b.	boring	1 2 3 4 5	enjoyable
c.	unsatisfying	1 2 3 4 5	satisfying

9. Which of the following teaching methods do you prefer?

a.	computer-presented material	Yes	No
b.	seminars	Yes	No
c.	reading textbooks	Yes	No
d.	reading journals	Yes	No
e.	discussion with staffmen	Yes	No
f.	discussion with colleagues	Yes	No
g.	bedside teaching	Yes	No

APPENDIX 6

THE POST-TEST EXAMINATION QUESTIONAIRE

1. Which of the following was the most common reason for accessing the CLINICAL REFERENCE LIBRARY?
   a. problem-solving ie. problem with the management of a patient
   b. continuing medical education
   c. recreation
2. How would you rate the CLINICAL REFERENCE LIBRARY.....
   a. compared to the library?
      useless 1 2 3 4 5 very useful
   b. compared to consultation with staffmen?
      useless 1 2 3 4 5 very useful
   c. compared to consultation with fellow colleagues?
      useless 1 2 3 4 5 very useful
   d. compared to attending seminars?
      useless 1 2 3 4 5 very useful
3. How would you rate the medical content of CLINICAL REFERENCE LIBRARY?
   a. worthless 1 2 3 4 5 valuable
   b. out-of-date 1 2 3 4 5 current
   c. contains errors 1 2 3 4 5 error-free
   d. medically imprecise 1 2 3 4 5 medically precise

4. How would you rate your level of overall competence in critical care medicine before using the CLINICAL REFERENCE LIBRARY?

   average or below average 1 2 3 4 5 outstanding

5. How would you rate your level of overall competence in critical care medicine after using the CLINICAL REFERENCE LIBRARY?

   average or below average 1 2 3 4 5 outstanding

6. To what degree do you feel that the CLINICAL REFERENCE LIBRARY added to your fund of knowledge during your rotation through the ICU?

   did not add 1 2 3 4 5 did add

7. Learning this material by computer was...

   a. a waste of time 1 2 3 4 5 time well spent

   b. boring 1 2 3 4 5 enjoyable

   c. unsatisfying 1 2 3 4 5 satisfying

8. Which of the following teaching methods do you prefer?

   a. computer-presented material Yes No

   b. seminars Yes No

   c. reading textbooks Yes No

   d. reading journals Yes No

   e. discussion with staffmen Yes No

   f. discussion with colleagues Yes No

   g. bedside teaching Yes No